Characterization of the Rookery Bay National Estuarine Research Reserve

Executive Summary

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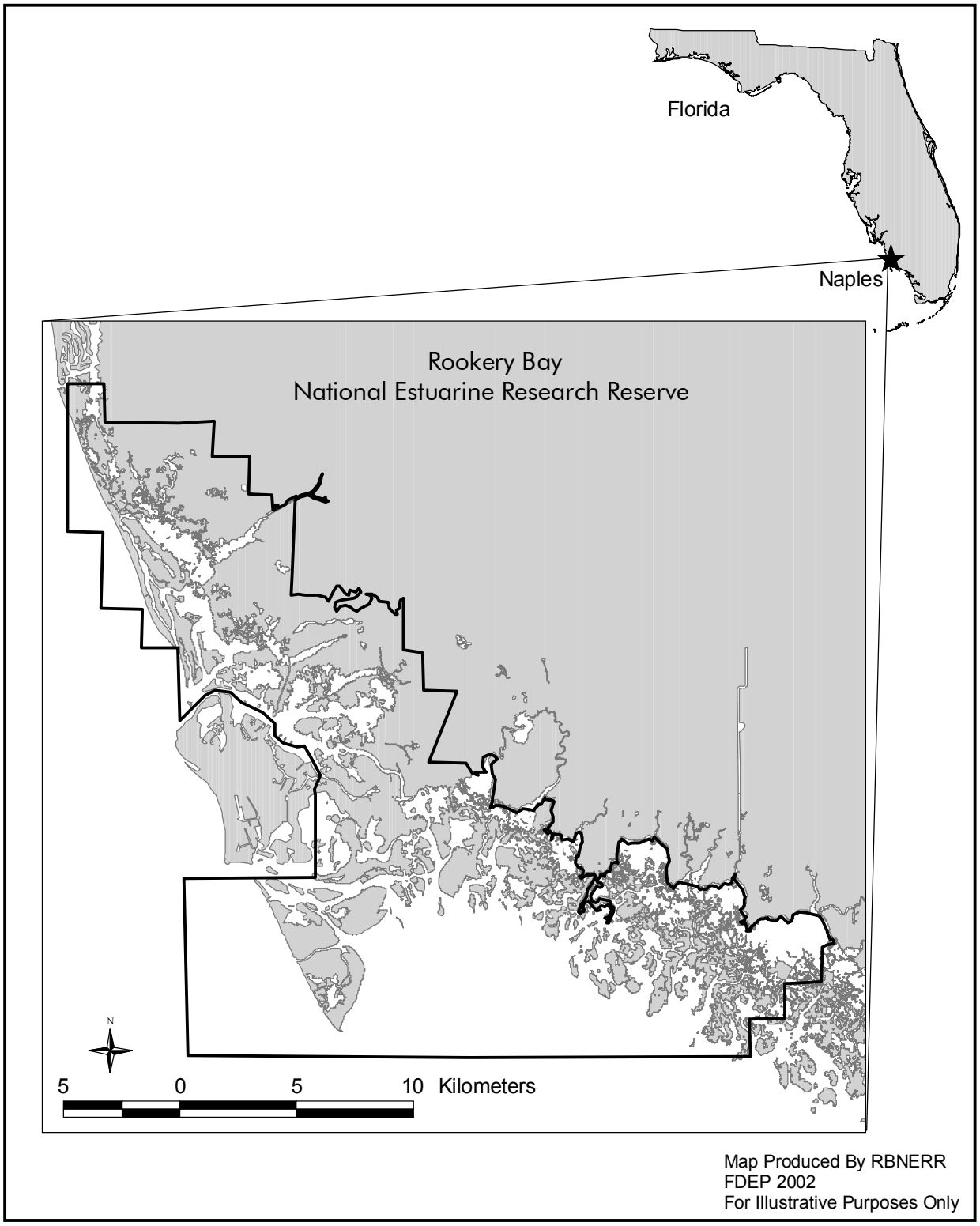
2001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FDEP 2002
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Characterization Of Rookery Bay National Estuarine Research Reserve

Executive Summary

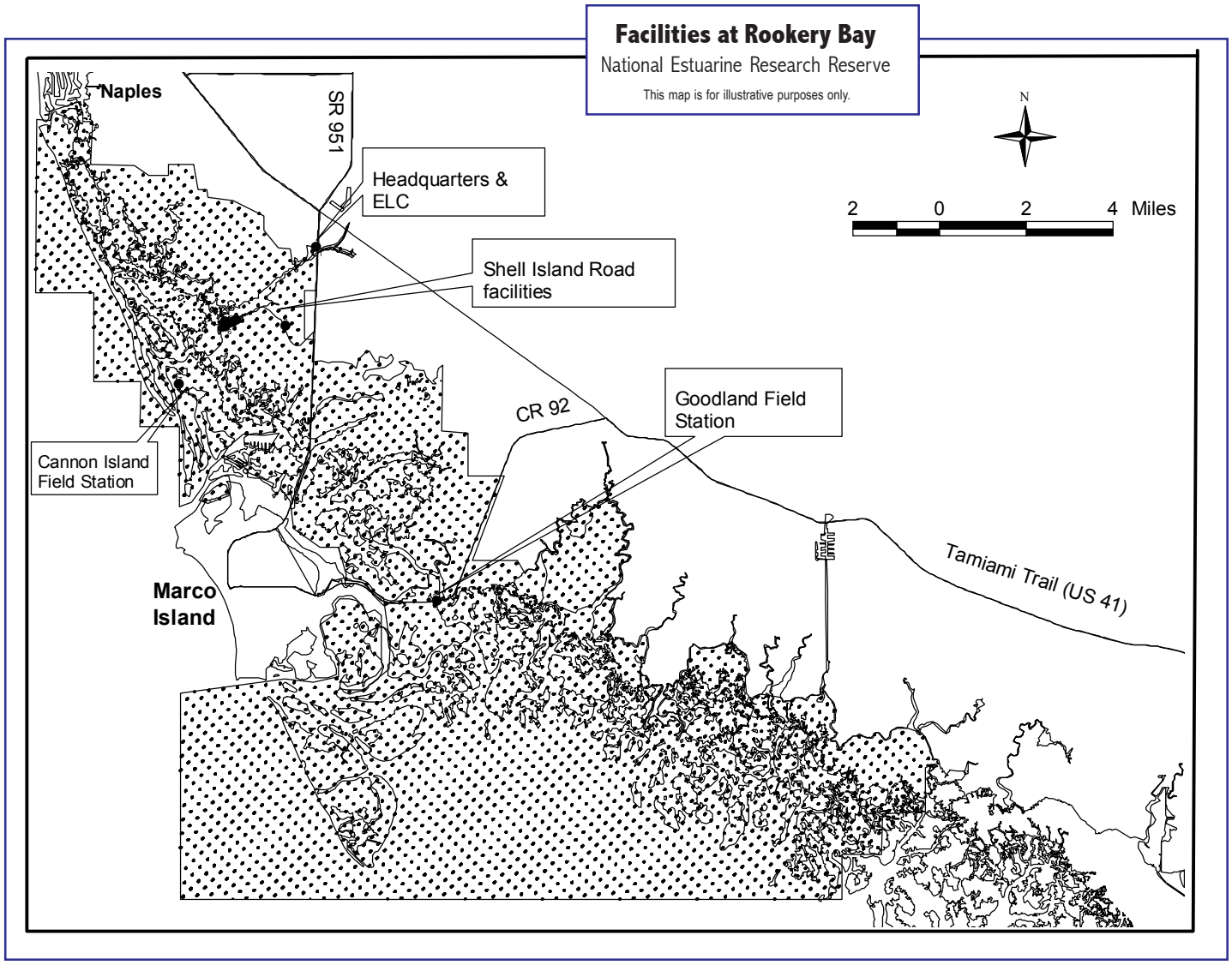
This CD-ROM characterizes the culture, ecology and resources in the Reserve, the surrounding state managed aquatic preserves and their watersheds. The information provided is intended for use by resource managers and researchers, and for anyone interested in estuary or watersheds.

ROOKERY BAY

GENERAL INFORMATION

The Rookery Bay and Ten Thousand Islands ecosystem is a prime example of a nearly pristine subtropical mangrove forested estuary. RBNERR is located in the West Florida subregion of the West Indian Biogeographic Region . The total estimated surface area of open waters encompassed within proposed boundaries is 70,000 acres, 64 percent of RBNERR. The remaining 40,000 acres are composed primarily of mangroves, fresh to brackish water marshes, and upland habitats. Rookery Bay has a surface area of 1,034 acres and a mean depth of about 1 m. Salinities range from 18.5 to 39.4 parts per thousand with lower values occurring during the wet season from May through October. Highest values occur during the dry seasons (winter and spring) and can exceed those of the open Gulf of Mexico (35-36 parts per thousand).

Approximately 3,772 acres within the RBNERR boundaries are leased to the Department of Environmental Protection (DEP) by NAS, The Nature Conservancy, and CSF. State-owned lands, including 70,000 acres of submerged lands and approximately 22,928 acres of acquired lands, are held in fee simple title by the Board of Trustees. Approximately 13,300 additional acres within the boundaries were acquired by the state as part of a settlement agreement with the Deltona Corporation. Parcels totaling approximately 500 acres represent privately-owned inholdings within RBNERR. DEP has designated all tidally connected waters within the boundaries of RBNERR and Cape Romano/Ten Thousand Islands Aquatic Preserves as Class II and Outstanding Florida Waters (OFW). OFW designation implements the state's highest standards for proposed developments, and does not allow for direct discharges that would lower ambient water quality, or indirect discharges that would significantly degrade water quality.



The Rookery Bay and Ten Thousand Islands ecosystem is a prime example of a nearly pristine subtropical mangrove forested estuary. The total estimated surface area of open waters encompassed within proposed boundaries is 70,000 acres, or about 64% of RBNERR managed areas. The remaining 40,000 acres are composed primarily of mangroves, fresh to brackish water marshes and upland habitats. Rookery Bay has a surface area of 1,034 acres and a mean depth of about 1 m. Salinities range from 18.5 to 39.4 ppt with lower values occurring during the wet season, from May through October. Highest values occur during the dry (winter and spring) season and can exceed those of the open Gulf of Mexico (35-36 ppt).

Owing to the influence of the warm-water Florida Current, the seasonal effects from the Gulf of Mexico Loop Current, and its geographical position at 26° N latitude, the average annual temperature in the Rookery Bay area is about 24°C (75°F). Winter temperatures range from -1°C (ca. 30°F) to about 26°C (75°F), with cooler days and nights (10-15°C) in the months of January and February. Warming trends in April and May are frequently modified by winds from the southwest off the Gulf of Mexico, and by late season cold fronts. Summer high temperatures approach 35°C (95°F).

Rookery Bay and vicinity have an annual rainfall of 50-55 inches (127-140 cm) per year. The heaviest average monthly rainfall, 8-9 inches per month, occurs from June through September. Lowest average rainfall, 1-2 inches per month, occurs from November through March. Approximately 66% of the total yearly rainfall occurs between the months of June and October. Southwest Florida lies in the seasonal tropical weather belt that channels hurricanes toward or along the coast. Historically, few severe hurricanes have come ashore. Donna, in 1960, and Andrew, in 1992, are the exception.

The original headquarters, and current lab facilities, are located on Shell Island Road, off State Road 951 and about

halfway between US Hwy 41 and Marco Island. A dock with slips for 15 boats extends into Henderson Creek a short distance from the opening into Rookery and Hall Bays. Headquarters is now located on Tower Road on Henderson Creek upstream from the Shell Island facilities. The future Environmental Learning Center will be located on Tower Road with a bridge across Henderson Creek. RBNERR has two dormitory facilities for visiting researchers, educators and resource managers – four beds in a restored gatekeepers house on Goodland Bay and 12 beds at the lodge on Cannon Island.

HISTORY

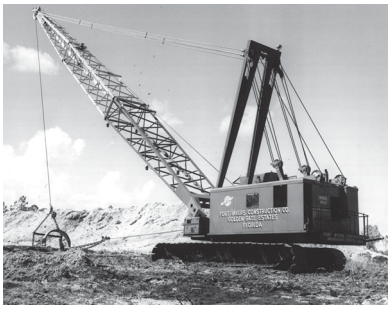
The southwest coast of Florida is young in geologic terms, with current mangroves and uplands forming less than 5000 years ago. The earliest documented habitation by human is about 3500 years ago, but its history since then is rich and filled with evidence of a network of native American settlements and tales of outlaws and brave pioneers seeking refuge and commerce in hostile, unknown territories.

The first recorded non-native settlements in Rookery Bay and southwest Collier County began in the late 1880's. Growth was slow despite the construction of the Tamiami Trail connecting Naples to Miami in 1928. Naples, and the surrounding area, has changed from the slow-paced fishing village in the 1960's to the sprawling urban resort area of today, with one of the highest numbers of golf courses in the U.S. Rookery Bay and its barrier islands were saved from development in the 1960's by the concerted efforts of local citizens concerned about dwindling natural coastal resources, and in 1977 lands surrounding the bay purchased for conservation were accepted into the National Estuarine Research Reserve System.

Preservation

In 1964, a group of Naples developers wanted approval from the Board of County Commissioners to extend Kelly Road across the intercoastal waterway and Rookery Bay area to islands and lands where they could build homes and condos. Outraged citizens dubbed the proposed road the "Road to No Where" and declared war. Key figures opposed to this road included Lester Norris, retired Texaco official and owner of Key Island, attorney George Vega, Charles Draper, retired Air Force Colonel, Joel Kuperberg, Naples City Councilman and botanist, Nelson Sanford, retired lumber executive, and Fred Winter, newspaper reporter. In the spring of 1964, attorney Vega appeared before the commission and unrolled a 50 foot petition down the middle of the board room and tacked the other end to the wall. "These are the people opposed to that road. Now, where are the people who want it?" The commission vetoed the road.

On April 11, 1964, the Collier County Conservancy and The Rookery Bay Committee were organized and the committee was charged with saving the estuary by buy the lands around it. Charles Draper, Lester Norris and Herman Teetor donated the first $2,500. Through private donations, a total of 2600 acres was purchased for the Rookery Bay Sanctuary. The state of Florida already owned and protected 1,400 acres of jurisdictional bay bottoms and wetlands in the RB area. Together the state's ownership and Audubon's stretched the boundaries of RB sanctuary to 4,000 acres. In 1977, the National Audubon Society leased the reserve to the Florida Dept. of Natural Resources and a management committee was established, chaired by Audubon, the Collier County Conservancy and the state's Natural Resources Department. Rookery Bay Sanctuary became Rookery Bay National Estuarine Research Reserve in 1978.



The Friends of Rookery Bay, established in 1987, has taken a leadership role in assuring that Rookery Bay National Estuarine Research Reserve continues to serve as an outdoor laboratory for visiting investigators from around the world, an outdoor classroom for thousands of students from around the United States, and a natural, historical, and cultural coastal asset for residents and visitors. The Friends

of Rookery Bay provides the support needed to maintain high-quality, on-site, estuarine education programs. It also sponsors off-site programs designed to address priority issues including increased demands on coastal resources generated from unprecedented urban development in the area. A well-informed public is better equipped to make sound decisions about the problems and issues facing the estuarine environment. The Friends of Rookery Bay, Inc., is a registered 501-c-3 non-profit citizen support organization that aids RBNERR through tax-deductible donations.

2003 Boundary Expansion

In 2000, DEP, supported by the Reserve Management Board, proposed that the original RBNERR boundary be expanded to incorporate adjacent state-owned coastal lands. In January 2003, the Reserve's expanded boundary was officially recognized by NOAA. The expanded boundary includes all the area currently managed by the Rookery Bay NERR staff as designated by the State of Florida Board of Trustees. The Reserve boundary now encompasses approximately 110,000 acres and represents an estuarine system extending from Gordon Pass to the north and all state-owned uplands and submerged lands within the Ten Thousand Islands region to the south. The DEP, supported by the Reserve Management Board, recommended this action to:

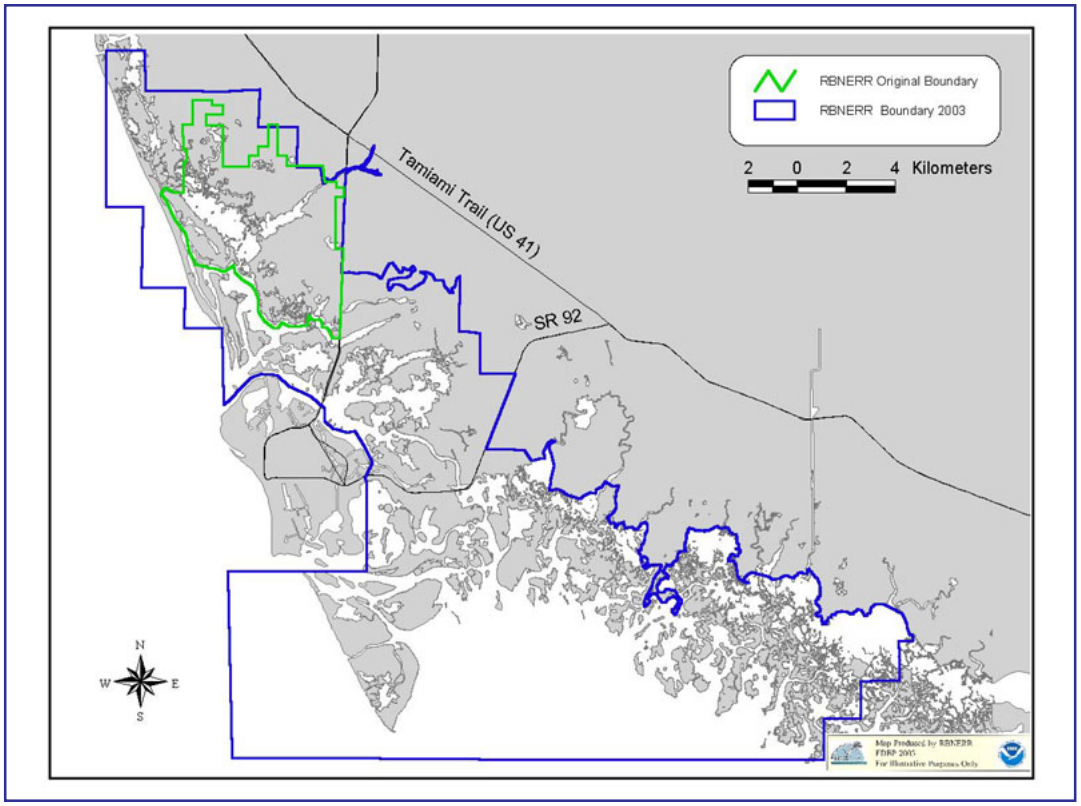
- Enable the Reserve to direct resources and associated federal funds to support active research, stewardship, and education programs for state-owned lands adjacent to Rookery Bay that represent a larger contiguous estuarine ecosystem.

- Provide a larger, more diverse estuarine ecosystem that is more representative of the West Indian Biogeographic Region.

- Designate adjacent coastal wetlands and islands, including the Ten Thousand Islands, as an estuary of natural significance.

DEP signed a lease agreement in 1990 with the Board of Trustees that provides management authority for all uplands identified in the proposed NERRS expansion. Title and authority for submerged lands management within the proposed boundary is provided for in Chapter 258 (F.S.). All lands located within RBNERR and the boundary expansion are essential components of a contiguous estuarine ecosystem, and will not be considered as surplus under current and planned management strategies.

Because the ecological characterization project was substantially complete prior to the official boundary expansions, most of the maps produced in support of this project represent the pre-expansion boundary.

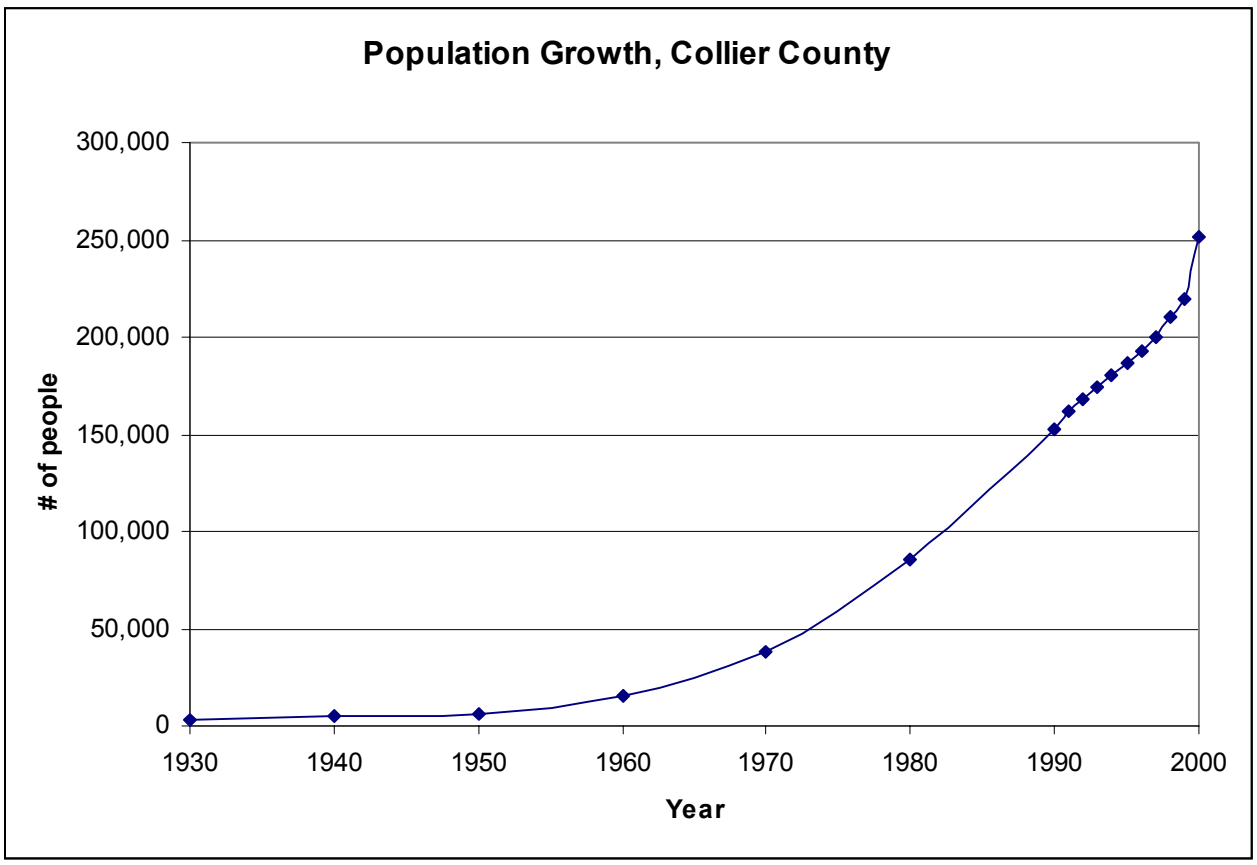


Archeology
The oldest dated formation found to date in western Collier County shows formation of this part of the Florida peninsula in the late Miocene era, or about 5.7 to 9.5 million years ago. This unnamed formation lies under the Tamiami Formation which is the current aquifer for western Collier County and was formed sometime during the Pliocene Era. During the Pleistocene Era, sea levels fluctuated with glacial activity. Terraces were formed across the Florida Peninsula at different elevations, and relic sand dunes can be found along these ridges even today. The two terraces in the Rookery Bay area were the Silver Bluff terrace at one to ten feet above current sea level and the Pamlico terrace varying between 18 and 25 feet.

Approximately 5,000 years ago, the current environmental conditions were reached in Florida, making it possible for human populations to occupy almost every part of Florida. In Rookery Bay, the mangrove and coastal estuaries had also been formed. In 1995, archeologists with the Florida Bureau of Archeological Research conducted a reconnaissance of approximately 12,000 acres of CARL Project lands within the Reserve. They recorded 20 sites – 11 pre-European and 9 from the late nineteenth and early 20th century homesteads. The earliest documented habitation sites in Rookery Bay date from about 2,500 years ago, with skeletal remains dating to 3,000 years ago.

SOCIO-ECONOMICS
Rookery Bay NERR is located in Collier County, one of the fastest growing counties in the U.S. Collier County is also home to a portion of the original Everglades water flow way and many other environmentally sensitive lands, such as mangroves. Over half of the county is in public ownership, managed by either state or federal agencies. These opposing land uses – rampant development and large conservation areas – create unique problems and opportunities for RBNERR. RBNERR staff work closely with private developers, regional planners, and the water management district to encourage plans that protect freshwater flows to the estuary and maintain important wildlife corridors, while meeting the needs of a growing population.

Agriculture, tourism, fishing, boating and commercial crabbing are other important revenue sources in Collier County, and the undeveloped areas of the Reserve and the Aquatic Preserve are heavily used year-round. Acquisition and restoration of watershed and barrier island land surrounding the Reserve is a high priority as a means of buffering the estuary from developmental pressure. However, once the land is in public ownership, conflicts over public access and recreational use arise. Balancing the need for estuary research, preserving rare habitats and educating the public through strategic access is a never ending management task.



Demographics

Collier County currently ranks among the highest in Florida's metropolitan growth rates and is considered one of the fastest growing areas in the nation. Between 1980 and 1998, County population increased 144 percent from 85,971 to an estimated 210,100. The county's population is projected to reach 289,500 by 2010, representing an increase of 38 percent over the population in 1998. By 2020, the population is projected to exceed 358,000 people.

During the winter season, an estimated 750,000 tourists and seasonal residents visit the area each year, additing to the population. This kind of rapid growth puts enormous pressure on environmental resources in any locality. In an area that historically was under several inches of water for three to six months out of the year, this kind of growth implies severe ecological impacts in the form of dredge and fill for housing; saltwater intrusion in and drawdown of aquifers from increased water consumption and drainage canals; and increased runoff of nutrients, sediment, and contaminants to and increased public use of sensitive estuaries.

Economic Valuations

Costs associated with typical goods and services are relatively easy to calculate. Property values are dependent upon a complex mix of location, amenities and aesthetics, but are largely determined by square footage and quality of building materials. The price of raw materials is determined by the labor and machinery required for extraction. All these factors—wages, overhead, capital costs, and transport—fluctuate with the strength of the currency and supply and demand, but they are well established in a monetary framework that fixes a dollar value on consumer products and information.

Naples, the Collier County seat, is known for its mild climate, tropical beauty, and waterfront location. This combination makes for high property values and creates a highly desireable area for living. Ironically, this attraction to the environment may inevitably lead to destruction of the services valued most in western Collier County—clean, clear water with abundant wildlife, fish, and lush vegetation. Environmental services are not traded commodities, and although we depend upon them for our life support, it is difficult to determine their monetary value. Is it the cost to restore or replace the structure and function of a mangrove or saltmarsh? Is it the cost of the sand and gravel required to filter water and recharge the aquifer? Can we rely on willingness to pay for aesthetics or recreation? Can we determine the value of an estuary by the future fish crop it will provide? Or will the value be determined in the future when natural resource supply is scarce and demand is high?

The most comprehensive economic valuation to date of ecosystem services and functions of estuaries and other natural systems estimate that a hectare of mangroves provides $9,990/yr in service, seagrasses provide $19,004/yr, estuaries and bays deliver $22,832/yr, and coastal waters offer $4,052/yr (Costanza et al. 1997). These values are based on a synthesis of non-market valuation techniques, including willingness-to-pay, costs of human-made, substitutable goods and previous estimates of natural capital, translated into 1994$.

Based on these values and acreage for each system within the Reserve and aquatic preserves, RBNERR provides approximately $407,250,000 in environmental services to Collier County and the State of Florida every year. This is more than ten times the estimated tourist revenue of $35,282,000 during the'93-'94 fiscal year (derived from tourism development taxes in Collier County, Pierce 1995).

Land Use Planning

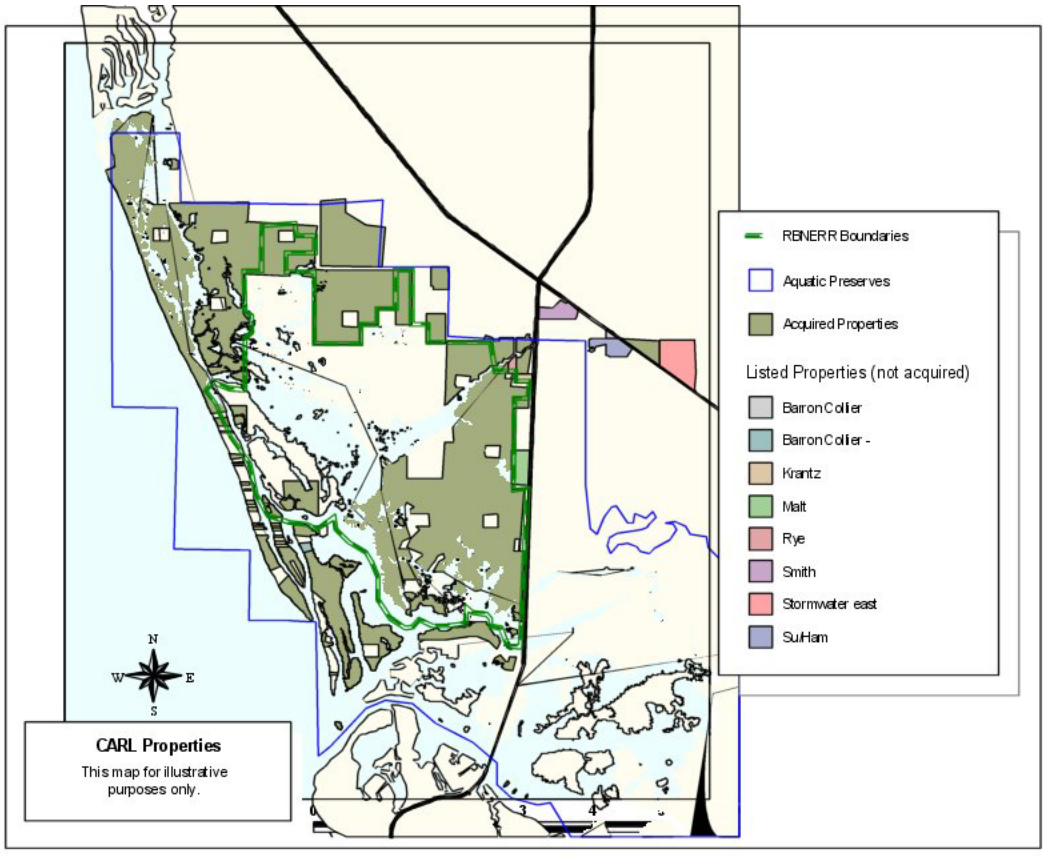
Comprehensive long range land use plans are required by the State of Florida. These are completed at two different scales – regional and county by county. Projections by the Collier County government anticipate continued rapid growth in the next five years, particularly along the State Road 951 corridor, and south of U.S. 41 (Tamiami Trail). These areas are designated as urban and directly adjoin the eastern and northern boundaries of the Reserve. The Collier County Comprehensive Plan presents criteria for development of county lands and provides a map with recommendations for land use.

Land to the northwest, south and west of the Reserve is designated as Coastal Resource Management/Recreation, and is restricted for large scale development. Smaller projects, including Planned Unit Developments (PUD's) may be permitted. The Florida Department of Community Affairs (DCA) has designated portions of Collier County, including the Big Cypress National Preserve and Fakahatchee Strand State Preserve as an Area of Critical State Concern (ACSC). Under the ACSC program, DCA reviews any development order for construction as defined by Florida Statutes, Chapter 380.04 for consistency.

Conservation

Collier County, the second largest county in the State, covers approximately 2,025 square miles of land. Over 50% of this area has been set aside under public or private ownership for conservation purposes, with RBNERR as one of ten large conservation areas.

NERRS Program Regulations state that a National Estuarine Research Reserve's boundaries "encompass an adequate portion of the key land and water areas of the natural system to approximate an ecological unit and to ensure effective conservation." In 1985, the DEP and CSF developed a land acquisition project boundary to purchase and incorporate privately-owned lands from willing sellers adjacent to the Reserve. The State's Conservation and Recreation Lands (CARL) Selection Committee approved the project boundary, enabling these lands to be eligible for purchase using CARL funds. The CARL project boundary was modified in 1995 to include additional parcels along Henderson Creek. The project's stated purpose is to protect RBNERR water quality, preserve habitat for native plants and animals, and to



provide recreational opportunities to local communities in Southwest Florida. Significant state funding was provided through Preservation 2000, enacted by the Florida legislature in 1990 to provide bond revenues to purchase environmentally sensitive lands. Additional federal funds were provided by NOAA and the U.S. Fish and Wildlife Service (USFWS). This important partnership effort represents an investment of approximately $57 million in CARL funds used to purchase and preserve essential lands for the RBNERR.

Public Access

Primary public use of RBNERR resources has traditionally been boating and fishing, but with rapidly growing population and tourism, all uses of RBNERR have increased, with carrying capacity surpassed in some areas. Initial steps taken by the Reserve to promote compatible public use included the construction of trails and boardwalks, installation of informational signage, and conducting workshops for the general community and targeted users. Despite these efforts, incompatible public use resulting in destruction or degradation of natural resources is increasing within the Reserve.

Through a community-based planning process, RBNERR is developing public access and visitor use projects that promote uses of Reserve resources that are compatible with the mission of RBNERR, ensures protection of key natural and cultural resources and keeps pace with the changing needs of local communities. Using existing authority provided by local, state and federal laws, appropriate policies will be established for public access and visitor use that ensure protection of important natural and cultural resources, working cooperatively with partner agencies and law enforcement to provide enforcement. Visitor outreach efforts will convey use policies and the need for them, and visitor use will be monitored to assess impacts to environmental conditions within the Reserve.

Recreation

While the Reserve provides important opportunities for compatible recreational use such as hiking, boating and fishing, the intensity of public use and the frequency of incompatible public use is increasing as resident and tourist populations in Collier County continue to increase at an unprecedented rate. Along with an increase in population, boating registrations in Collier County have increased dramatically since 1986, with a total of 18,240 registered boaters in 1998. RBNERR staff have observed a significant increase in use of recreational boats, including personal watercraft, within RBNERR since 1990. This trend is expected to continue as the population increases. Boating can result in impacts to RBNERR wildlife and resources, such as the West Indian manatee and wading bird rookeries.

During the winter season, an additional estimated 750,000 tourists and seasonal residents visit the area each year. However, a 5 year RBNERR boating survey shows a long-term average difference of only 19% between seasonal and non-seasonal use of the Reserve waters.

ECOLOGY

Many habitat and land use maps, created even in the 1990's, depict the entire coastal fringe of southwest Collier County as solid areas of mangroves. While it is true that mangroves are the predominant wetland in and around the Reserve and the Ten Thousand Islands, the communities of Rookery Bay National Estuarine Research Reserve and its watersheds are a rich and varied mosaic of saltwater, freshwater and upland ecosystems. There are over 500 plant, 22 mammal, 90 bird, 210 fish, 60 crustacean and 40 reptile and amphibian species documented in the Reserve.

The plant communities of southwest Florida have been historically categorized several different ways. Five of these are presented in Davis (1943). Florida Natural Areas

Inventory (FNAI) and the contributors to Ecosystems of Florida (Meyers and Ewel, 1990) have suggested more recent classifications for all of Florida. A classification scheme that is appropriate for a specific Reserve, however, needs to meet criteria determined by management issues, scale of management or research, and site-specific structure and function. This section presents 22 classifications based on pertinent management practices, primarily fire and inundation requirements, and, in some instances, susceptibility to exotic plant colonization. The descriptions provided are based on vegetation because this is the easiest recognizable feature and have been tailored to specific findings in the RBNERR communities representative of each class where available.

TERRESTRIAL & FRESHWATER SYSTEMS

The majority of acreage landward of the mangrove/saltmarsh fringe managed by Rookery Bay National Estuarine Research Reserve (RBNERR) is pine flatwoods. Scrub and freshwater marsh are the next largest communities represented. There are small holdings of cypress, palm-oak hammocks and abandoned agriculture, and a few very small examples of tropical hardwood hammocks. Many of these communities have wide ecotonal margins, and occasionally, a surprise to newcomers in the area, upland and freshwater communities stand directly adjacent to mangroves and saltmarshes.

John Davis, in his 1943 USGS publication, was one of the first scientists to document the extent and composition of natural communities in south Florida. His work, although narrative and largely anecdotal, gave a good description of the mosaic of habitats and the soils that supported them that were prevalent throughout the area. However, because Rookery Bay NERR's mangroves are a unique opportunity for research, the Reserve's upland and watershed community functions are largely undocumented by any scientists. Of the remaining communities, cypress stands, only a small percentage of RBNERR's holdings, have extensive evaluations in nearby areas. Inventories and species lists abound for other communities, but empirical data on structure and function specific to the Rookery Bay area or southwest coast are scarce.

Scrub and Pine Scrub

This community includes oak scrub, rosemary scrub, coastal oak and palmetto scrub, but pine scrub is a separate category due to a different fire interval. Scrub is found on higher elevations and excessively well-drained soils, but not always white or light colored sands. It is rarely inundated. The most extensive scrub area in the Reserve is located on Shell Island Road, but a large section of rosemary scrub and mixed oak can be found inland from Sand Hill Creek.

The overstory is dominated by a mix of scrub oaks (*Quercus geminata, Q. myrtifolia, Q. chapmanii*) and/or rosemary bushes (*Ceratiola ericoides*). There is usually a dense understory of gallberry (*Ilex glabra*), staggerbush or rusty lyonia (*Lyonia fruticosa*), saw palmetto (*Serenoa repens*), lichens (*Cladonia* spp.) and spike moss (*Selaginella arenicola*). Scrub is less susceptible to invasion by non-natives than other wetter communities. Fires are infrequent, about one every 20 to 80 years. Frequent fires in oak scrub appear to favor succession towards pine scrub. Fires in rosemary scrubs, on the other hand, tend to leave large, long-term gaps in vegetation.

Pine scrub is actually a subset of scrub, but is differentiated from oak and rosemary scrubs because of different fire regime. The community class includes scrub with sparse pine canopy, scrubby flatwoods with an ecotonal mix of scrub and pine, and the few rockland pine areas found in the Reserve. Higher elevations and well-drained soils characteristic of oak scrubs also define pine scrubs. Several small examples of these communities occur in RBNERR as raised and circular "islands" in the middle of mangrove forests. These are sometimes called xeric flatwoods.

The understory vegetation found in scrub is also found in pine scrub (*Ilex glabra, Lyonia fruticosa, Serenoa repens, Cladonia* spp., *Selaginella arenicola*). Unlike oak

scrubs, the dominant canopy is South Florida slash pine (*Pinus elliottii* var. *densa)* with an oak (*Quercus* spp.) mix. Fires are frequent, every 3-7 years. Because of the high fire threshold of pine, relative to oak, frequent scrub fires favor succession towards pine scrub.

Hammocks, Palm/Oak and Tropical Hardwood

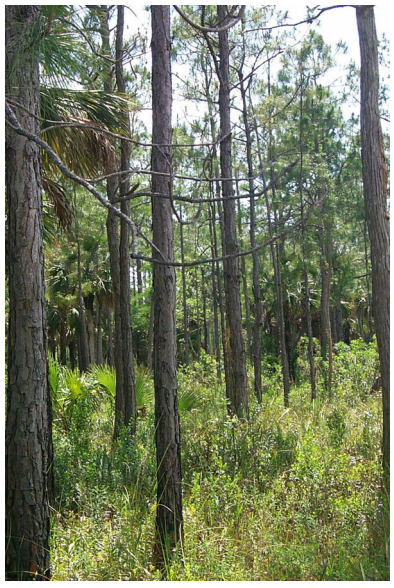
There are about 120 acres of cabbage palm hammocks in RBNERR managed areas. This community is closely associated with pine flatwoods and usually occurs in areas with seasonal ponding or wet depressions. Palm and oak hammocks are a coastal example of temperate broadleafed evergreen forests (Platt and Schwartz 1990).

The dominant overstory species in RBNERR is a mix of cabbage palms (*Sabal palmetto*) and live oak (*Quercus virginiana* var.). The percentage of each tree species varies and the canopy cover ranges from sparse to dense cover. Slash pines (*Pinus elliottii* var. *densa*) are occasionally present, and become dominant in the ecotone between this hammock and surrounding flatwoods. These hammocks are susceptible to incursion by invasive plants, and often have dense patches of Brazilian pepper (*Schinus terebinthifolius*) near disturbed areas such as roads. Fires are infrequent, about one every 20 to 80 years. More frequent or intense fires appear to favor succession to palm-pine hammocks (Myers 1985).

There are only about 40 acres of tropical hardwood hammocks in the reserve, with the largest single community located on Cannon Island. RBNERR has hammocks on sand and shelly ridges, limestone outcroppings and some shell mounds. Plants favoring alkaline conditions thrive on these ridges, some natural and some of them enhanced by the Calusa Indians. The dominant canopy species are gumbo limbo (*Bursea simaruba*), live oak (*Quercus virginiana*) and cabbage palm (*Sabal palmetto*). The understory is highly diverse, and epiphytes are well represented. These hammocks have fewer invasive species than other communities, but Brazilian pepper is often found at the perimeter. These areas are rarely inundated, and have infrequent fires (+26 to 100 years).

Pine Flatwoods

Pine communities are the dominant upland habitat at Rookery Bay NERR. Both mesic and hydric flatwoods are present in the 1,020 acres within the managed boundary. The dominant canopy is South Florida slash pine (*Pinus elliottii* var. *densa)*, and there are few if any *Quercus* spp. present. The common understory is saw palmetto (*Serenoa repens)*, gallberry (*Ilex glabra),* wax myrtle (*Myrica cerifera),* and wiregrass (*Aristida* spp.*),* with density and species dependent on level of moisture and fire frequency. Pine flatwoods are susceptible to invasion of non-native species, particularly *Melaleuca quinquenervia* and Brazilian pepper.



This community is characterized by flat topography and poorly drained soils resulting in slow runoff and seasonal inundation. Dry season moisture is dependent upon litter cover and depth to hardpan, with hydric flatwoods occasionally exhibiting a dry surficial layer but saturated conditions just below the ground surface. The elevational difference between this community and adjacent cypress and marsh communities is often 1-2 inches. Fire frequency ranges from 3 to 7 years. In RBNERR these communities are often found adjacent to mangrove forests.

Pine flatwoods have the highest diversity of any south Florida community – 361 species compared to 306 in hardwood hammocks (Beever and Dryden 1993). This hydric community is considered by some to be a rare success ional stage between marsh and hardwood hammock (Duever 1976). Another theory suggests that hydric pines are a distinct south Florida habitat well adapted to cycles of flood, drought and fire (Beever 1993). This seasonally wet forest is a jurisdictional wetland at the federal level, but not for the state of Florida. During the wet summer season, periphyton mats can become as thick as 4 cm (Beever and Dryden 1993). Due to the algal cycle of

productivity and respiration, abiotic factors in the forest floor exhibit significant diurnal fluctuations, similar to wetlands and shallow lakes. This community is prime habitat for the endangered Florida panther, the Florida black bear and red-cockaded woodpeckers (Beever and Dryden 1993; Kautz 1994). Twenty-three percent of southwest Florida's pineland was lost to agriculture and urban development between 1943 and 1970 (Birnhak 1974). The remaining stands are susceptible to melaleuca competition, especially along edges of fragmented parcels (Myers 1984).

Cypress – Savannah/Prairies, Strands, Domes

Cypress forests are a significant part of the southwest Florida landscape. However some ecologists believe that cypress has expanded into a geographic region "to which it is not particularly adapted" (Myers 1984), and that the introduction of *Melaleuca quinquenervia* is forcing it back to areas with more optimal conditions. Southern cypress trees have two leaf variations, creating some dissension about number of species. One viewpoint supports two species, bald cypress (Taxodium distichum) and pond cypress (Taxodium distichum var. nutans or Taxodium ascendens) (Myers 1984, Ewel and Odum 1984, Brown et al. 1984), and the other recognizes only bald cypress with leaf variations arising from extreme environmental conditions (Duever et al. 1984).

Three different landscape formations of cypress are obvious in Collier County, and RBNERR has small examples of all three within the Reserve boundary - savannah/prairies/shrub/dwarf, strands, domes . Studies conducted between 1972 and 1976 in the Belle Meade watershed (Brown et al. 1984) and Fakahatchee Strand (Burns 1984) show that strand cypress has the highest productivity (158 to 180 tonnes biomass/ha), followed by drier domes (80 to 95 tonnes/ha) with prairies, or shrub cypress, having the lowest total production (~30 tonnes/ha/yr). This community is a preferred habitat for the Florida panther (Kautz 1994).

South Florida cypress prairies are a subset of scrub-shrub wetlands and include marl prairies. These communities are sometimes called dwarf cypress savannas and are located on limestone outcroppings with a thin soil substrate. The CARL property on the north side of Hwy. 41 is RBNERR's only example of this community, more frequently found further east in the Big Cypress Preserve.

The dominant overstory species is pond cypress (*Taxodium distichum* var. *nutans* or *Taxodium ascendens*), but the canopy is sparse and the unique growth structure is often called hatrack cypress. Vegetation is dominated by herbaceous marsh species, and, in RBNERR, is mostly grasses (*Panicum* spp.) and sedges (*Cyperus* spp.). Overall vegetative diversity is low. All disturbed cypress areas are prone to *Melaleuca quinquenervia* invasion. Fire is more frequent in this community than other cypress stands, several per year in some cases (Ewel 1990), but because litter accumulation is low, fires are not intense. The hydroperiod is determined almost exclusively by rainfall, and frequent dry periods oxidize litter, preventing peat buildup.

Cypress strands are a forested wetland associated with slow-flowing water on sandy substrates, creating the characteristic winding stream, or strand, landscape pattern. There are about 190 acres of cypress strand in the northwest section of the RBNERR managed areas.

The dominant overstory species is pond cypress (*Taxodium distichum* var. *nutans* or *Taxodium ascendens*), but hardwood species are also present – red maple (*Acer rubrum*) and red bay (*Persea borbonia*). *Thalia geniculata* and *Sagittaria latifolia* are common understory species. Brazilian pepper and *Melaleuca*, invasive non-natives, are frequently found at the perimeter. Fire is infrequent (20 – 100 year frequency); strands are not considered to be fire dependent habitats. Strands have a connection to the surficial aquifer, and consequently have longer periods of inundation than cypress prairies. They do, however exhibit seasonal water fluctuations.

Cypress domes are a forested wetland associated with depressions and long hydroperiods, creating the characteristic circular or oval landscape pattern, with shorter trees on the perimeter and taller trees in the center, creating the dome shape typical of this system. Often, domes have a center circle with a depressional marsh. There is one cypress dome in the northwest section of the RBNERR managed areas, but without a center marsh.

The dominant overstory species is pond cypress (*Taxodium distichum* var. *nutans* or *Taxodium ascendens*), but hardwood species are also present – red maple (*Acer rubrum*) and red bay (*Persea borbonia*). *Thalia geniculata* and *Sagittaria latifolia* are common understory species and bromeliads are frequent. Brazilian pepper and *Melaleuca*, invasive non-natives, are frequently found at the perimeter. Fire is infrequent (20 – 100 year frequency); domes are not considered to be fire dependent habitats. Domes have longer periods of inundation than cypress prairies. They do, however exhibit seasonal water fluctuations.

Marsh – Flatwood and Wet Prairie

Flatwood herbaceous marshes are adjacent to pine flatwoods, and, in RBNERR, are characterized by maidencane (*Panicum* spp.*)* and duck potato (*Sagittaria latifolia*). Flatwood marshes usually have a distinct circular shape with abrupt transition to pine and saw palmetto flatwoods. These marshes are inundated 6-9 months a year and fires are infrequent (10 years). Periodic drying is essential to maintenance of these marshes. Impoundment causes root loss and plant dieoff, regardless of water depth. There are a few isolated examples of this community in the northwest section of the RBNERR managed areas and off of County Road 951 – probably less than 100 acres.

Wet prairies, a sometimes expansive community, occur adjacent to scrub, pine scrub, flatwoods, cypress and saltmarsh, and make up about 400 acres in RBNERR's northwest managed areas. They are characterized by saw grass (*Cladium jamaicensis),* cattails *(Typhus* spp.*),* and maidencane (*Panicum* spp.*)* in what appears to be large monotypic stands. However, even dense growth of these tall grass-like species supports a high diversity of true grasses, sedges, ferns, vines and deeper water marsh plants. Cattail thrives in areas of excess nutrient runoff. Invasive plants include *Melaleuca quinquenervia* and *Lygodium microphyllum* (Old World climbing fern).

Fires are frequent in the large saw grass prairies in the Everglades to the east of RBNERR, and all wet prairies are dependent upon frequent fires (1 – 7 years) to recycle nutrients. Wet prairies are flooded only about 6 months a year, and the extended dry period, coupled with fire, are crucial to maintaining saw grass stands.

Developed

Residential, agriculture, commercial, golf course and mining land uses are the main development surrounding Rookery Bay NERR. Residential uses include single-family, zero lot-line villas, two to three story apartment, townhouse and condominium buildings and mobile home parks. There are no high-rise condominiums, such as those on the skyline of Marco Island, at this time. The corridors along US Hwy 41 (Tamiami Trail) and SR 951 are a mix of shopping centers, gas stations, automotive repair and junkyards, nurseries, tomato and bell pepper production, motels and restaurants. Two auto repair and junkyard operations are located directly adjacent to marshes at the edge of the Reserve. Sand and gravel are the mined commodities.

Concomitant with development are roads and, in SW Florida, canals for flood protection. Retention ponds are required for all new development by the SFWMD – size and depth determined by amount of impervious surface. These water systems now provide year-round freshwater in an area where freshwater has historically been ephemeral. Many of the retention areas are connected to the larger creek and canal system drain-

ing the landscape. All of these developed areas contribute to nutrient and contaminant loading to RBNERR's estuaries via this drainage system, without the historic benefit of filtration provided by the long period required for sheetflow to reach the bays following summer rains. Development also brings ornamental and non-native vegetation, clear cutting and filling of native ecosystems and temporary sediment loading to canals and downstream estuaries.

ESTUARINE & SALTWATER SYSTEMS

Estuaries are the broad ecotone connecting upland and freshwater communities to bays and oceans or gulfs. The width of this area of mixed communities is dependent upon the elevational slope of the coast and the tidal range. The tidal range in this area of the Gulf of Mexico is about 1 meter. RBNERR and surrounding areas have a less than 1 foot per mile slope, and the natural five foot elevation contour is north of US Highway 41, from 3 to 7 miles from the coast. Hwy. 41 was built at an elevation of 5 feet, and in addition to connecting Miami to Naples, it has acted as a saltwater barrier ever since.

The southwest coast of Florida is a low energy coast, rarely experiencing killing frosts. Furtther, the coastal shelf extends outwards for many miles, creating a shallow basin with numerous calcareous outcroppings. These conditions favor the development of mangroves over saltmarsh, creating the unique maze of mangrove islands making up the Ten Thousand Island area and the barrier islands closing in Rookery Bay.

Saltmarsh/Saltflats

Saltmarsh is not as extensive in RBNERR as the rest of the coastal United States, and is almost always intermixed with scattered buttonwood (*Conocarpus erectus*) and other mangrove species, primarily black mangrove (*Avicennia germinans*). The differentiation between high and low is an important mosquito control differentiation, and is based on the usual height of the dominant species, rather than on elevational differences.

High marsh, the more frequent marsh in RBNERR, is dominated by needle rush (*Juncus roemerianus)* with a mix of salt grass (*Distichlus spicata)* and sea purslanes (*Sesuvium* spp.), and is usually found on the backside or inside of mangroves. Low marsh, or cordgrass (*Spartina alterniflora* or *bakeri*), is rare in this area where the ocean edge is dominated by mangroves. Kice Island, bordering the Gulf, has a small patch of *Spartina* on the open water side of the mangroves, and there are scattered patches at the edge of the intercoastal waterway, to the east of Keewaydin Island. A mix of *Spartina*, salt grass and purslanes is present in a few inland areas with tidal influence – along Hwy 951 and in the northwestern section of the Reserve.

Saltflats and saline ponds are infrequent in RBNERR's mangrove areas. Saltflats are characterized by high soil salinities and absence of vascular vegetation. They are, however, populated by macroalgae, microalgae, and bacteria. About ten of RBNERR's salt flats have small, mostly circular saline ponds. These saline ponds are differentiated from other larger open water lagoons in mangroves by the lack of tidal connection or influence, and characterized by low levels of plant litter.

These communities are not fire dependent, and are rarely subject to invasive non-native plant species. However, Brazilian pepper is often found on slightly elevated perimeters of *Juncus* stands.

Mangroves

Mangroves are the most extensive vegetated habitat in the RBNERR managed areas – about 36,000 acres. Based on peat accumulation rates, mangroves have been in South Florida for approximately 6,500 years (Lugo and Snedaker, 1974). The obser-

vations by Shier (1969), within the Ten Thousand Islands region, indicate that Vermetid reefs form the nuclei of most of the outer barrier mangrove islands whereas oyster bars form the nuclei of most of the inner lagoon mangrove islands.

The same three mangrove species are present in varying degrees of dominance in these four forest subsets: red mangrove (*Rhizophora mangle)*, black mangrove (*Avicennia germinans)*, and white mangroves (*Languncularia racemosa).* Several ground cover plants are common in mangrove forests, despite the closed canopy: sea purslanes (*Sesuvium* spp.), saltwort (*Batis maritima*), glasswort (*Salicornia virginica*), and ferns (*Acrosticum* spp.). Buttonwood (*Conocarpus erectus*) is often found in white mangrove stands in the northwest section of RBNERR managed areas. Red mangroves (Family Rhizophoraceae) possess stilt, prop or buttress roots and produce the most highly developed viviparous propagules. Black mangroves (Family Avicenniaceae) have characteristic breathing organs called pneumatophores extending up out of the ground from the roots. White mangroves (Family Combretaceae) are atypical mangroves in that they have partial vivipary and less visible root adaptations.

The mangrove forests of the Reserve are comprised of four basic forest types: fringe forests, riverine forests, overwash forests and basin forests. These habitat types represent a continuum of tidal inundation and freshwater influence. Fringe mangrove forests are comprised of mangroves that fringe the coasts of lagoons, tidal creeks and embayments. These forests are inundated daily by tides and are dominated by red mangroves. Riverine forests extend along rivers and creeks that receive significance amounts of terrestrial freshwater input. These forests produce the largest trees and are dominated by red mangroves. Overwash forests are islands that are flushed by tides completely and frequently. They are dominated by red mangroves and occasionally contain black and white mangroves. Overwash forests have uniform ground surface elevations slightly above mean sea level. Basin mangrove forests are inland to the fringe and riverine forests; these forests are flushed by tides infrequently and are dominated by black and red mangroves. Black mangroves dominate areas with higher soil salinity and sulfide concentrations. At extreme inland locations, basin mangrove forests with the least frequent tidal exchange and most extreme fluctuating soil salinity conditions are usually composed of a mixture of stunted red and black mangroves. (Lugo and Snedaker, 1974; Odum et al., 1982)

In general, mangroves appeared to be more productive than seagrass, marsh grass and most other coastal systems. Most sport and commercial species of South Florida appeared to be linked to food chains originating from mangrove detritus (Lugo and Snedaker, 1974). Zieman et al. (1984) found that, within the Reserve, pink shrimp were more dependent upon plankton and algae from mangroves than these food sources in seagrass. Sheridan (1992), found during a survey of the macrofauna within seagrass, open water and fringe mangrove forest habitats of Rookery Bay, that twelve fish and eight crustacean species were caught more often in mangrove habitats. Total benthic population densities in mangroves also exceeded those in adjacent seagrasses and non-vegetated mud (Sheridan, 1997). RBNERR benthic population densities are equal to or greater than those found in highly productive seagrass habitats elsewhere in the southeastern United States.

ISLANDS

The Ten Thousand Islands Aquatic Preserve is managed by RBNERR staff, and about 9000 of the islands fall into the Preserve boundaries. The remaining area is managed as part of the Everglades National Park. Some of these 9000 islands fall under joint management responsibility with the U.S. Fish and Wildlife Service Ten Thousand Islands Wildlife Refuge. Most of these islands are mangrove overwash islands: mangroves rooted on deep substrates of peat and sediment built up over vermetid reefs. Some of the islands have higher central shell and limestone ridges supporting coastal

strand and other upland communities. A few along the outer edge facing the Gulf of Mexico have narrow sandy beaches and low dunes.

Vegetative species and communities have been extensively inventoried on islands surrounding Rookery Bay having beach, dune or upland communities (see species lists). Most of these communities are xeric or mesic with the exception of mangroves on the baysides (Burch 1998, Burch 1996, Craig 1991). There has been little research into productivity or system dynamics, again with the exception of the mangroves and changing shorelines. A study on dune systems is currently in progress (2001-2002), conducted by a RBNERR Research Fellowship recipient.

A long term study of shoreline changes on Florida's sandy beaches has been conducted by the University of Florida's Coastal Engineering group (Dean et al. 1998). Rookery Bay's barrier islands are part of this study. Between 1971 and 1998, the greatest changes are evident in areas of channel dredging – Gordon Pass and Big Marco Pass. The rate of change at Gordon Pass is 15.1 ft/yr and 21.2 ft/yr at Big Marco. The range of change, not including these channeled areas, is from 0.7 ft/yr to 8.9 ft/yr.

Beach/Dune and Coastal Strand

Beaches and dunes, universally recognized ecosystems, are characterized by areas of shifting sand and beach grasses. There are a few areas with sea oats (*Uniola paniculata)*, but the more common ground covers in the RBNERR managed areas are sea purslane (*Sesuvium maritima)*, sandspurs (*Cenchrus* spp.), spurges (*Chamaesyce* spp.) and morning glory vine (*Ipomoea pes-caprae*). Fire in this area is rare, and this habitat is not considered fire dependent.

Wide sandy beach areas are not as common in the Reserve or Aquatic Preserve areas as on the east coast due to differing energy intensities from wave action. The few areas of existing beach are almost all on outlying barrier islands and are subject to constant migration from offshore and channel currents, as well as from downstream affects of dredging and built structures such as jetties and sea walls.

Coastal strand, the xeric area behind dunes with low growth (stunted) forms, is not present in all RBNERR island areas. Many beach areas are short intermittent stretches that transition directly into mangrove forests without a dune or strand area. Some large and notable coastal strand communities can be found on Shell Key, Four Brothers Key, Dismal Key, and Fakahatchee. This community is characterized by sandy, raised elevations with a mix of cactuses, dune plants and an occasional gumbo limbo. Cactuses are a dominant feature (*Cereus pentagonus* and, *Opuntia* spp.), with sea grapes (*Coccoloba uvifera)* and nickerbean (*Caesalpinnia bonduc)* as other common plants. Fire is infrequent (20-80 years). These areas are particularly susceptible to non-native lather leaf invasions.

One species of interest in coastal strand areas is the Florida thatch palm, *Thrinax radiata*, previously thought to be extinct on the southwest Florida coast. A small healthy patch has been found on Key Island, on Reserve property. Several islands have coastal scrub communities characterized by cabbage palms and several threatened and endangered cactus. These communities are not found on the mainland.

MARINE

About 64% of the area managed by RBNERR (both Reserve and Aquatic Preserves) is marine habitat – open water and benthic. Most of this managed area is less than 3 feet in depth, with tidal ranges from –0.8 ft to 4.1 ft. Next to mangroves, fish populations in this marine environment are the most studied resource in the Reserve, with about 100 species present throughout the Aquatic Preserve. Consolidated substrates in RBNERR managed areas support oysters, worm reefs, seagrass and sponge beds,

with over 130 species of benthic invertebrates identified. Unconsolidated substrates are often covered with macroalgae mats. Current research by RBNERR focuses on water quality, fish and crab populations, seagrass location and density and bathymetric mapping.

Benthic

Oyster reefs, seagrasses, unconsolidated substrates and macroalgae mats are the predominant benthic habitat throughout the bays and backwaters of both the Reserve and the Aquatic Preserves. Sponge beds and worm reefs are evident, but the extent and locations of coverage are not documented.

The primary seagrasses for the region managed by the Reserve are *Halodule wrightii* (shoal weed), *Halophila englemanni* (star grass), *Syringodium filiforme* (manatee grass) and *Thalassia testudinum* (turtle grass) (Nalley et al.,1997). Other attached submerged vegetation include the algal species *Caulerpa verticillata*, *Caulerpa sertularoides* and *Acanthophora spicifera* (Nalley et al., 1997). Accurate aerial seagrass surveys in the area managed by the Reserve are limited to coastal water habitats because low visibility of backwater estuarine water limits their usefulness.

Most data regarding the occurrence of seagrass in backwater estuaries in the region has been obtained through records of bycatch associated with bottom trawls (Yokel, 1975; Colby et al., 1985). These data indicate that some loss of seagrass habitat has occurred. Research conducted by Carter et al. (1973) in 1972 described Fakahatchee Bay as having dense stands of turtle grass and shoal weed. Similarly, in a study conducted in 1971 and 1972, Yokel (1975) described the western section of Fakahatchee Bay as having dense sands of shoal weed, with light to moderate quantities of turtle grass. Ten years later, Colby et al., (1985) found that 97% of the samples contained little or no seagrass. Browder et al. (1986) also reported little or no seagrass in Fakahatchee Bay during studies conducted in 1984 and 1985.

Thoemke and Gyorkos (1988) collected 129 species of benthic invertebrates in Rookery Bay, Hall Bay and Henderson Creek. Based on the species composition of this collection, compared to sites with documented eutrophication, the researchers concluded that there was no evidence to suggest that the Reserve was experiencing nutrient enrichment. Sheridan (1997) comparing benthic infaunal abundances within intertidal habitats concluded that the infauna of seagrass and non-vegetated mud habitats were more diverse than that of the mangrove habitat. However, total densities were always higher in the mangrove habitat.

The Ten Thousand Islands and the estuaries around Marco Island were, at one time, the most productive and extensive southern quahog (*Mercenaria campechiensis*) harvesting area in the United States (Godcharles et al., 1973). Harvesting began in 1880 and declined in 1947, coincidental with an outbreak of red tide (Godcharles et al., 1973).

Macroalgae is a frequent bycatch reported by trawl studies in the area . The algae assemblage is dominated by the red algae, *Bostrychia scorpioides*, followed by the green algae *Boodleopsis pusilla*. Twenty-two other algal species, including nine chlorophyta and thirteen rhodophyta were also recorded.

Shirley and Haner (1997) studied the population dynamics of crabs on oyster reef habitats in Henderson Creek and Blackwater River from May 1996 to April 1997 relative to salinity fluctuations. This study concluded that the altered freshwater inflow into Henderson Creek was adversely affecting stenohaline crab populations. The Reserve staff continues to monitor crab populations on oyster reefs within Henderson Creek and Blackwater River and has expanded this study to include Fakahatchee Bay and Faka Union Bay.

CENTER FOLD PAGE - habit

Open water

Rookery Bay NERR and the Cape Romano – Ten Thousand Islands Aquatic Preserves cover a total of about 110,000 acres, 68,300 acres in open water. Beyond the channels maintained for navigation, much of these waters are shallow, and support a high diversity of fish, plankton and invertebrates. Beginning in 1999, the Reserve staff has conducted ongoing otter trawl collections in Fakahatchee Bay, Faka Union Bay and Pumpkin Bay. A Henderson Creek collection began in 2000. The purpose of this ongoing study will be to monitor the changes in fish populations in association with watershed hydrological restoration projects underway in the Henderson Creek and Ten Thousand Islands watersheds. In addition, data being collected at the Reserve's continuous water quality monitoring stations will be used to assess the effects of physicochemical conditions on fish populations.

Most information concerning the Reserve's fish populations comes from trawl studies. Unfortunately, due to differences in methodology and locations, direct comparisons of these studies are problematic. During the 1970s, the number of species caught in individual studies ranged from 59 to 96. In studies conducted from July 1982 to June 1984, 71 species were collected. Included in this dataset were 882 otter trawls which collected 18,252 fish representing 71 species. Studies completed by Reserve staff in the 1990s exhibit a range of 57 to 77 species.

Several researchers have used the size and abundance data collected from trawl studies to infer patterns of recruitment and spawning. Yokel (1975a) reported that silver jenny recruitment occurred in August and September. Weinstein et al. (1977) indicated that silver jenny exhibit a fall spawning cycle, with peak numbers collected beginning at the onset of the dry season until water temperatures dropped markedly. Yokel (1975a) indicated that recruitment by pinfish occurred in December to April with the onset of the rainy season serving as a cue to move offshore to spawn. Weinstein et al. (1977) also reported that pinfish appear to use inshore habitats as a nursery. Yokel (1975a) also indicated that silver perch recruitment occurred from March to July with the highest abundance in March through August and lane snapper recruitment occurred between June and October with the highest abundances recorded between June and October. Pink shrimp in the Ten Thousand Island region are also thought to use these waters as a nursery ground, spending two to six months as juveniles inshore, before contributing to the Sanibel grounds fishery (Costello and Allen, 1986).

Plankton sampling has also been used to determine spawning cycles and bay-specific larval recruitment patterns. In general, spring was the peak concentration of all ichthyoplankton. The concentration of fish larvae in bayward transport was nearly twice as great in Fakahatchee Pass as in Faka Union Pass. These studies demonstrated the negative effects of excessive canal discharges associated with the Faka Union Canal on larval fish recruitment.

AQUIFERS, SURFACE WATER

The principle source of drinking water in southwest Collier County is a shallow, or Chokoloskee Aquifer. This aquifer is recharged primarily by rainfall. Most of this formation is underlain by the Tamiami Formation, a thin, highly permeable layer with the top exposed in some areas. The Hawthorne Formation, present in north Collier County, is absent in the Reserve and Aquatic Preserve boundaries. The Floridian Aquifer lies beneath the Tamiami in southwest Collier County and extends out into the coastal shelf. The top of this formation is about 400 ft down at the coast. There are artesian flows from this aquifer in RBNERR areas, but the water is heavily mineralized and therefore not potable. An additional aquifer has recently been identified, and cores from RBNERR watersheds indicate that this gray limestone aquifer is present in the Preserve area.

There is some concern over increasing saltwater intrusion into these aquifers (McCoy

1974). A significant increase in the area of mangrove forests has been observed by some researchers, even into areas formerly supporting cypress (Alexander and Crook 1973). In 1974, chloride concentrations in the 951 Canal were as high as 381 mg/l, in excess of the 250mg/l recommended by the National Academy of Science as acceptable upper limits (McCoy 1974). During the same study, the Lely Canal chloride concentration was >500 mg/l. Retention ponds in developments on Marco Island and near the Belle Meade grade exhibit permanent chemical stratification from saltwater intrusion. The Belle Meade grade is an historic trail bed formed by connecting natural ridges with filled sloughs, and is still visible between the eastern shore of Henderson Creek near Shell Island Road and the abandoned agricultural areas to the east of Cnty. Rd. 951 and south of the Fiddler's Creek development. Marshes and groundwater immediately south of the Grade are hypersaline (who? When?).

Historically, lakes are mostly absent from the watersheds in southwest Collier County due to the flat topography and rare solution holes prevalent in the rest of peninsular Florida. In natural coastal fringe and island areas, freshwater is scarce and ephemeral, and when pockets occur, they have important, if short-lived, ecological significance (Davis 1943). With the advent of retention areas and man-made lakes, an important shift in the wildlife, invertebrate and algal network is occurring. The long-term effects of this interference remain to be seen, but, as with canals, they are likely to be significant.

SOILS

Soils exert considerable control over ecology at all scales. At the larger watershed scale, the physical characteristics of soil determine recharge, runoff, and evaporative losses. At the ecosystem scale, abiotic and biotic soil parameters determine vegetative communities and wildlife habitat. At a pedon, or soil column scale, soil chemistry determines nutrient and contaminant transport or sequester.

When combined with other spatial attributes, soil maps become an effective resource management tool. Relative elevation, slope and soil class can be used to determine restoration potential, particularly important for lands under consideration for acquisition and as direction for future development in areas surrounding conservation areas. Soil permeability, capacity and depth to water table can be used to determine recharge areas and overall watershed water budgets, important for conserving flowways and regulation of freshwater inputs to estuaries.

RESOURCE MANAGEMENT

The Reserve's stewardship activities were initiated in 1990 and a formal staffed program developed in 1993 to address the stewardship, restoration and land acquisition needs for the Reserve. Since that time, this program has worked effectively to maintain the ecological integrity of the Reserve to provide a stable environment for research and education consistent with the NERRS mission.

Key elements of the RBNERR resource protection strategy:

- ·Facilitating public acquisition of key lands associated with the Rookery Bay and Ten Thousand Islands ecosystems to help ensure long-term preservation of resources..
- ·Identifying essential habitats within RBNERR.
- ·Working in cooperation with federal and state agencies to protect listed species such as the West Indian manatee, American crocodile, Florida scrub jay and loggerhead sea turtle.
- ·Working with the regulatory and development community to address potential impacts associated with planned development projects within the watersheds of the Reserve.
- ·Designing and conducting restoration of disturbed wetlands, altered watershed

inflows, and plant communities infested with invasive non-native plants.

DIVERSITY

The Reserve's Resource Management Program is responsible for implementing science-based management to conserve natural biodiversity by recommending and implementing approved strategies to (1) protect the natural resources of the Reserve and it's watershed; (2) identify needed hydrologic and habitat restoration within the Reserve and its watershed; (3) restore natural conditions to the fullest extent possible using the best available techniques; and, (4) export information on management and restoration activities to environmental managers and decision makers. The primary goals are to protect and restore natural ecological functions within the areas managed by the Reserve through invasive species control, prescribed burn management and hydrologic restoration of wetlands and to assist in the recovery of endangered species through cooperative efforts with private landowners, and local, state and federal agencies and organizations. A primary function of the Resource Management program is to identify and pursue acquisition, management and restoration of natural resources at the watershed, community, habitat and site levels by coordinating with federal, state, local and private entities to affect watershed-scale restoration and conservation.

Fire

Natural communities within RBNERR, including scrub, pine flatwoods, marshes and wet prairies, are dependent upon fire to maintain species composition and diversity. Lightning has been the main source of fire ignitions throughout the evolution of the South Florida landscape, although humans have been influencing the fire regime for thousands of years. In the last hundred years increased human intervention in the form of hydrologic alterations, creation of artificial firebreaks (e.g. roads, canals), fire suppression, and intentional and accidental ignitions has severely disrupted the natural fire regime. Alteration of natural fire intervals is considered one of the major ecological impacts of humans on the South Florida ecosystem.

Controlled burns are now used extensively in fire-dependent habitat to eliminate potential fuel for arson and wildfires. Prescriptions are written for fires, so that burning occurs under selected, controlled conditions, while protecting life and property from damage.

Multi-species habitat management

A multi-species environment relations model has been implemented to attain the goal of preserving biological diversity of Rookery Bay National Estuarine Research Reserve (RBNERR). The traditional approach to fauna and flora management focussed upon species. For practical reasons, there are simply too many important species in the Reserve to handle on a species-by-species approach. Larger-scale approaches, at the level of habitats and ecosystems, are the only way to conserve existing biodiversity. A multi-species - environment relations model can be used to pose new questions about the roles and relationships of species in habitats and how managers might provide for species' ecological functions through ecosystem management.

Ecosystems are defined by their structure and function. The model uses a relational database to keep track of fauna and flora species along with the functions and structure they contribute to and tolerate and their range of distributions. In this model, structure is labeled as key environmental correlates (KEC) and function is key ecological functions (KEF). Key environmental correlates are abiotic or biotic conditions of a species' environment that proximately influence the fitness of individuals and viability of populations. Key ecological function refers to a species' main ecological roles that influence diversity, productivity, or sustainability of ecosystems. A given KEF can be shared by many species, and a given species can have several KEFs.

Invasives/Non-natives

Much of southwest Florida has been invaded by invasive plant and animal species. These species displace native vegetation and turn once biologically diverse systems into near monocultures with minimal diversity. The Invasive Plant Control Plan was developed to focus invasive plant control efforts at the Reserve: identifying the invasive species and areas of likely infestation; presenting methods for controlling these species, including physical, chemical and biological; targeting priority sites; and tracking reinfestation rates and levels of maintenance required for habitat restoration.

Rookery Bay NERR has been involved in habitat restoration through invasive plant control for more than ten years. Control has been accomplished through staff and volunteer efforts, as well as contractual services, using chemical, mechanical and hand removal, depending upon the site conditions. These activities are funded through many different sources, including in-house management funds, grants, mitigation, and private landowners. The balancing of parcels for priority based on funding options generally begins with projects that are adjacent to existing or on-going control sites to maximize effectiveness by decreasing the adjacent invasive plant seed source and concentrating efforts.

Restoration

Habitat and hydrologic restoration efforts at Rookery Bay encompass a variety of activities, including control of invasive plants and, when applicable, planting of native plants, removal of abandoned roadbeds and filling of associated canals and ditches, GeoWebbing existing access roads, construction and installation of stormwater management systems and control structures, installation of culverts, and re-contouring of filled and/or disturbed areas based on historic site composition. Both type of funding and timing of funds play a role in prioritizing projects. Priority based on funding options generally begins with projects that have altered hydrology where restoration will have an expansive impact and with projects that are strictly invasive plant control given lower priority.

Some projects focus on partnering and supporting efforts by other agencies within the watershed. While Rookery Bay may not be the lead agency, there is a vested interest in the restoration and Rookery Bay may contribute funds through grants, assisting with mitigation or through in-kind services. The list of potential restoration projects for the Reserve is extensive, and while challenging, it is also realistic. Development is occurring at an unprecedented rate. This development provides opportunity for numerous project specific mitigation efforts. Additionally, Rookery Bay has successfully received 10 grants in the past 5 years, totaling more than $5.5 million, toward acquisition and restoration efforts.

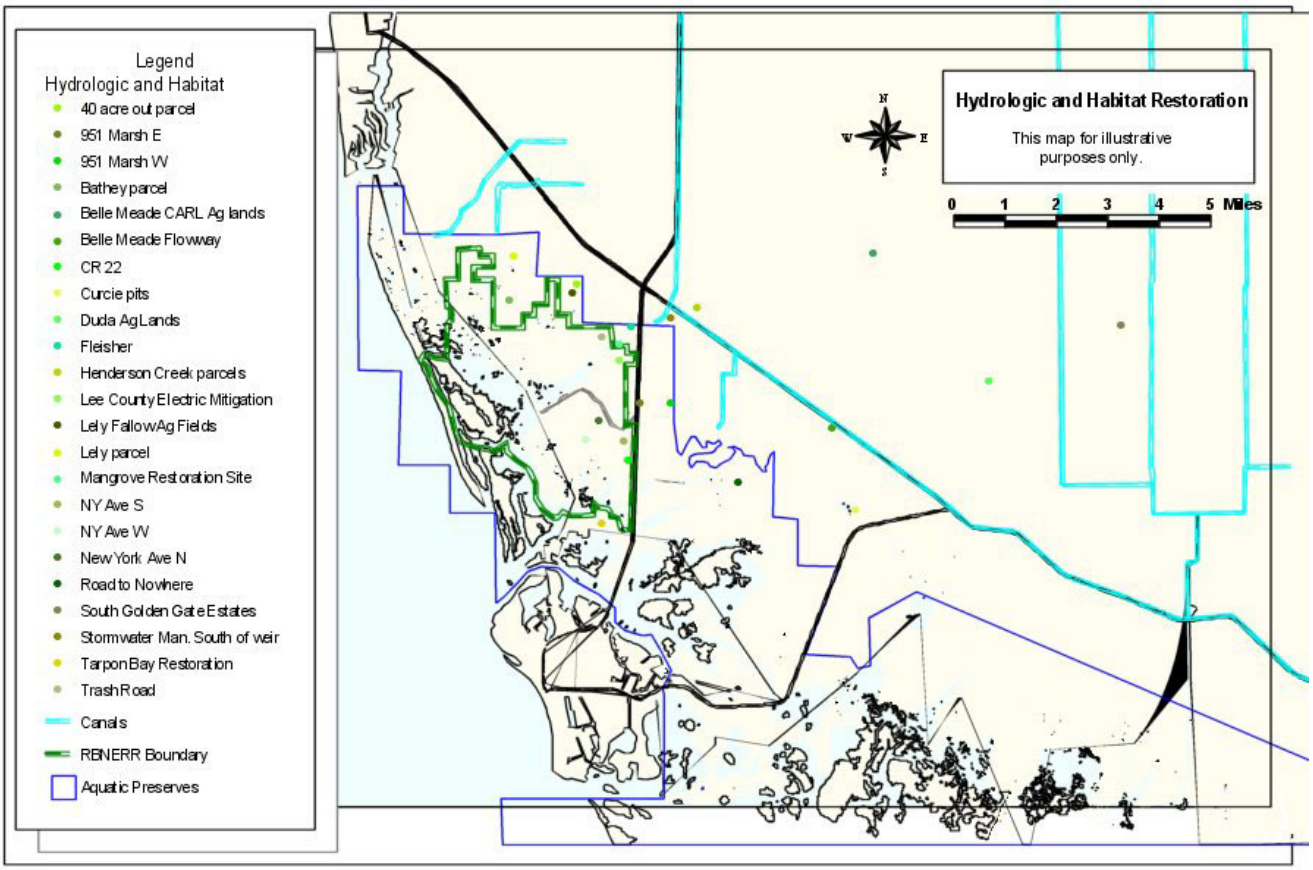
Rookery Bay's Conservation and Recreation Lands (CARL) Project, supplemented by funds from USFWS and NOAA grants, has been successful in acquiring 97% of the project which includes lands critical to long-term protection of the natural and cultural resources. An estimated $50 million has been expended to acquire primary, secondary and tertiary barrier islands, as well as inland parcels that buffer the Reserve, connect hydrology and habitats, and protect water quality entering the estuaries. In addition to the Rookery Bay CARL Project, four acquisition projects have been funded through the US Fish and Wildlife Service's National Coastal Wetlands Program, and are contiguous to the Reserve's boundaries: (1) Keewaydin Island Acquisition - acquisition of critical primary barrier island habitat; (2) Cape Romano – acquisition of a primary barrier island complex; (3) Henderson Creek – acquisition of critical parcels that connect the watershed to the estuary; and, (4) the Ten Thousand Islands – acquisition of remaining outparcels within this extensive network of mangrove islands.

Current acquisition efforts focus on remaining inholdings (surrounded by state owned and managed lands), outparcels (adjacent to state owned and managed lands) and connector parcels (connecting critical hydrologic flowways and habitat corridors). These lands are primarily upland sites that buffer existing Reserve protected areas. Some of these sites are in pristine condition and some will require restoration. The disturbed sites targeted for acquisition include areas within or adjacent to flowways within the watershed that need to be protected, lands that serve as wildlife and habitat corridors, areas that can function as stormwater retention sites for water quality protection and parcels that are buffers to pristine Reserve lands.

WATERSHEDS

Watershed alterations are a key issue in protecting RBNERR estuaries. Much of the surrounding property is zoned for development in the fastest growing area in the United States. The Reserve goal is restoration of natural freshwater inflow quality and quantity, to the fullest extent possible, by promoting conservation of natural flowways through cooperative efforts with federal, state and local agencies, organizations, and private landowners. The Reserve staff attends monthly and periodic permit review meetings hosted by the regulatory agencies and provides comments to private developers and regulatory agencies when requested. In the future, the Reserve will host an annual watershed workshop for regulatory staff, including City, County, DEP, Water Management District, Florida Fish and Wildlife Conservation Commission, US Army Corps of Engineers, US Fish and Wildlife Service, National Marine Fisheries Service and US Environmental Protection Agency, to review the status of the Reserve's watershed and discuss options for preservation, restoration or reconstruction of flowways and habitats.

Prior to development of southwest Florida, stormwater moved slowly through wetland strands and sloughs and in a sheet of overland flow from Lake Okeechobee to the Gulf of Mexico. The underlying soils have limited storage capacity during summer rainy seasons, with ponding of much of the area from 3 to 6 months every year. Stormwater in the southwest section of Collier County is now managed by a series of interconnected canals with different kinds of control: fixed crest weirs, pumping, manually operated flood gates, and flood gates with electronic sensors. These structures perform several functions: holding saltwater back in tidally influenced areas, retaining water on land during dry seasons, and releasing stormwater to prevent flooding of urban areas. Control of these flowways may increase protection of property, but it alters the natural salinity fluctuations that estuaries require to maintain natural diversity throughout the foodweb.



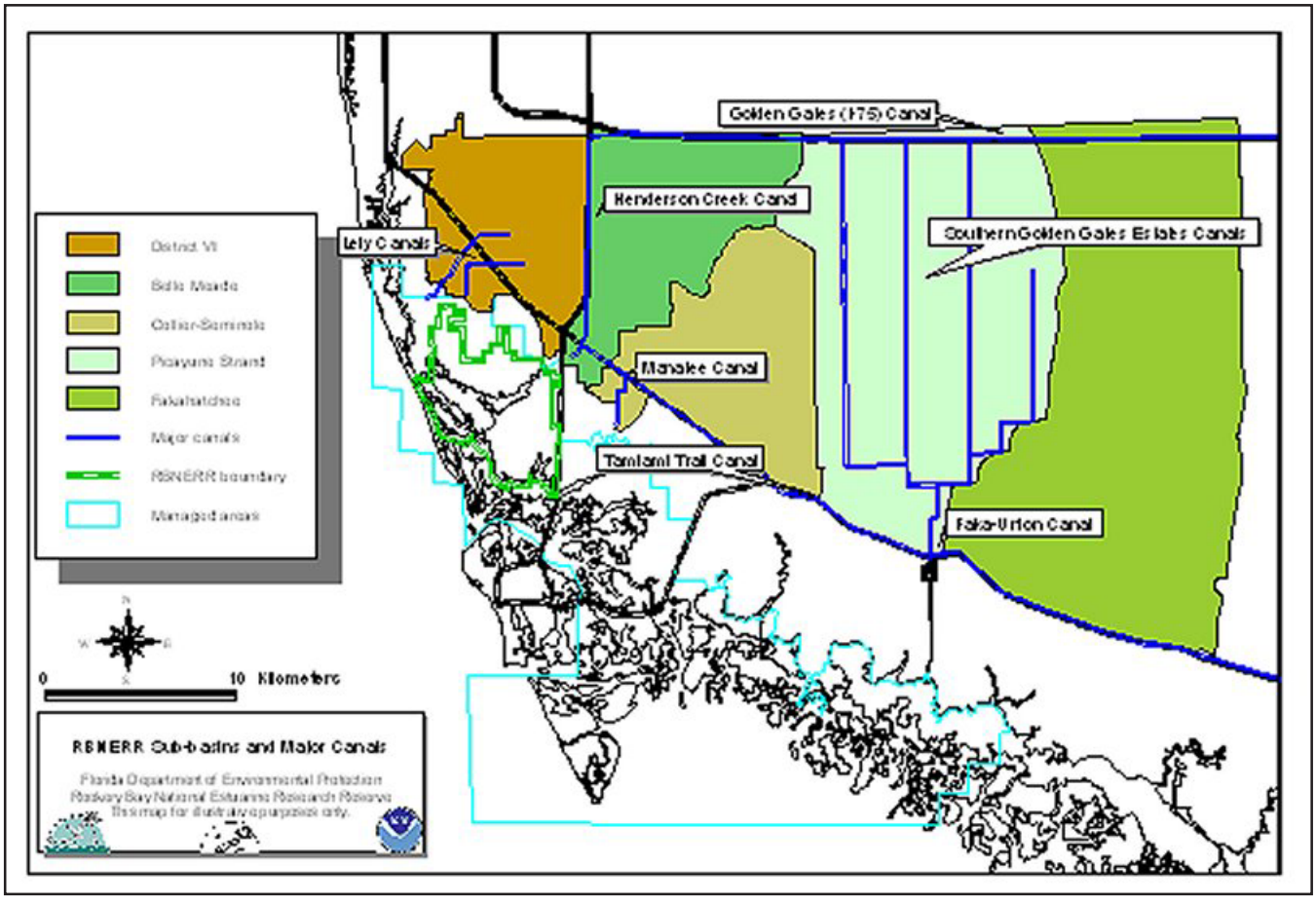
Canals with the greatest impact on Rookery Bay are the Henderson Creek Canal, the section of the Tamiami Trail Canal that drains into Henderson Creek, and the Lely Canals.

Henderson Creek is the main tributary to Rookery Bay. Historically, the creek had two headwaters in the Belle Mead watershed, but one of the headwaters was dredged and connected to a canal draining SR 951 and most of the south-western side of the Belle Meade. Just south of the intersection of SR 951 and US 41, Henderson Creek intersects with the Tamiami Trail (US 41) canal. The 951 Canal drains a mix of cypress and hardwood swamps, commercial and light industrial areas, with recent extensive residential and golf course developments. The Tamiami Canal drains agricultural acreage, also with recent residential and golf course developments.

Just upstream of the intersection with the Tamiami Canal, the creek is constrained by a water control structure – the Henderson Creek Weir. This weir has operable gates that are opened in anticipation of floods and closed during the dry season. Control structures like this change the salinity fluctuations that tidal creeks and bays depend upon for maximum productivity and health. Collaboration between Rookery Bay NERR, the National Marine Fisheries Service and the South Florida Water Management District resulted in a retrofit to make the weir opening more responsive to natural water levels.

The Henderson Creek Weir retrofit was funded by the National Marine Fisheries Service, and in April 2001 the South Florida Water Management District computerized the opening and closing of the weir to naturally mimic the historic and dynamic flow of the creek into the estuary. Prior to the retrofit, the structure was a top-opening, gated weir opened manually during periods of heavy rainfall. Water control structures change the time, quantity and quality of water flow, and canals channel water quickly through the watershed, reducing the filtration and retention normally provided by surrounding wetland systems. Monthly trawls in Rookery Bay showed that abrupt salinity changes associated with rapid watershed flushing during the rainy season led to stress of many bay organisms and the decline in total number of animals collected with each survey. These surges of freshwater will be controlled with the retrofit, allowing return to more natural salinity fluctuations.

The South Florida Water Management District (SFWMD) has delineated five sub-basins that drain into Rookery Bay or the surrounding Aquatic Preserves, but there is a large amount of undelineated land below Hwy 41 that is already



developed or available for future development adjacent to estuaries and tidal creeks. Each of these areas has a very different pattern of development with unique environmental issues. Residential of differing densities, golf course, commercial and agriculture are the main land uses. There is some sand and gravel mining as well. Little of the overland flow above Hwy. 41 reaches the downstream estuaries and a SFWMD project to increase the number of culverts, thereby increasing connections, is currently underway.

District VI has large tracts of residential and golf course use, and drains via the Lely Canals and overland flow into estuaries at the north end of Rookery Bay. These land uses lead to loss of wildlife corridors between fresh and saltwater habitats, eutrophication from fertilizer, loss of invertebrates and bioaccumulation from pesticides and other contaminants, and sediment/silt transport into sensitive mangroves during construction. Commercial areas increase impervious surface and are a potential source of contaminants.

The **Belle Meade** drains into Henderson Creek Canal, the main tributary to Rookery Bay. The majority of the watershed is natural area, but development is concentrated at the mouth of the sub-basin, short-circuiting treatment provided by passing through natural areas farther up in the watershed. This watershed is undergoing a conversion from septic tank to centralized sewage treatment that should reduce fecal coliforms in Henderson Creek.

The **Collier-Seminole** basin drains into the Tamiami Canal and into Blackwater River, and the area immediately below it drains throughout the mangroves south of Rookery Bay. Agriculture is the primary land use and related problems are aquifer draw down from water consumption and drainage ditches, pumping of water into canals during wet seasons increasing freshwater point sources to estuaries, and excess fertilizers and pesticides. Further, agricultural fields that have been out of production for many years are now slated for development or restoration, but have residual pesticides that require treatment prior to flooding and reconnection to the area hydrology. There is the opportunity, however, to implement a master strategic plan that restores flow ways while permitting judicious development.

The **Picayune Strand**, also known as the Southern Golden Gates Estates, is almost completely natural, with the exception of a residential area along the Faka-Union Canal. However, the entire area was drained by a series of interconnected canals almost 20 feet deep and over 20 feet wide in the late 1960s and early 1970s. The area was never developed and now belongs to the state. It is slated for restoration beginning in 2002 as part of the Everglades Restoration effort. Until then, the Faka-Union Canal remains a freshwater point source to the Faka-Union Bay, while the Ten Thousand Islands estuary communities on either side have adjusted to receiving little if any overland flow.

Fakahatchee is largely natural and in state ownership. Downstream estuaries will still benefit from increased connection with the upper watershed through additional culverts under Hwy. 41.

ENVIRONMENTAL CONTAMINANTS

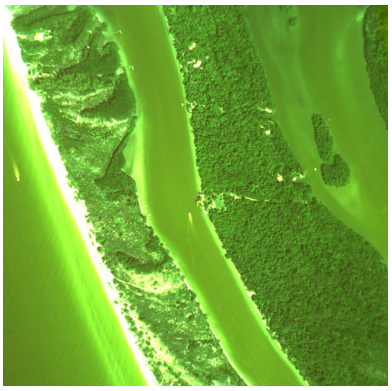
Although Rookery Bay and other Aquatic Preserve estuaries are surrounded by extensive state and federal conservation acreage, development and agriculture are situated at locations with critical influence on water quality. The city of Naples and Gordon River sit at the top of the RBNERR boundary with currents bringing contaminants from Naples Bay and the river into Rookery Bay. District VI subbasin, with tributaries into the northern Reserve mangroves, is over 60% developed and still growing. Intensive development lines the middle reach of Henderson Creek – Rookery Bay's main tributary – all with septic tanks when first built, and new golf course com-

munities now line over 1/2 of the Henderson Creek Canal's entire length. Agricultural land makes up 30% of the Collier-Seminole watershed – a subbasin bordering the Tamiami Canal with culverts into coastal estuaries and directly connected to Henderson Creek. Development is spreading into saltmarshes and mangrove fringes to the north of McIlvane Bay.

Metals, pesticides, petroleum products, sewage and fertilizers are the predominant sources of contaminants entering the estuaries managed by the Rookery Bay NERR. Pesticide from mosquito control applications has also been found to deposit within the Reserve. Monitoring of the Reserve's watershed indicates that fenthion (McKenney *et al.*, 1993); chlordane (Brandt-Williams and Shirley, 2000); cadmium, copper, lead, zinc, d-HCH, endosulfan sulfate (Grabe, 1996); metolachlor, atrazine and mercury (Miller *et al.*, 1999) are found in elevated concentrations. RBNERR staff, in partnership with Collier County, the City of Naples, SFWMD and various academic researchers, continue to monitor problem areas in both the estuaries and their watersheds.

GIS MODELS

Natural resource management is a science influenced by the constraints of the landscape. Wildlife have territory requirements, plants have environmental limits, hydrology is determined by soils and elevation – all of these are dictated by a complex, composite matrix of spatial features, or attributes. For example, an acre of land on top of a lime outcropping with a soil pH of 8, a thin layer of sand, 10 feet above the water table supports a very different community than the acre adjacent to it that is 3 feet lower in elevation, has two feet of acidic organic material and saturated conditions four months out of the year. These spatial variations determine important management issues such as conservation of flow ways and availability of habitat for endangered species.



Since these management issues are spatial in nature, it naturally follows that an information system capable of tracking many different attributes for any given piece of acreage, both many feet down into the ground below it and up to the atmosphere that rains on it, would be of great use to resource managers. This geographic information system (GIS) goes beyond making the maps that take up a lot of room in most naturalist's offices. GIS allows rapid access to the features of importance to a specific issue without having to deal with extraneous lines and information. It also permits spatially explicit simulations of impacts from increasing development or projections of succession following disturbance. Each attribute defines a particular physical event that occurs when rain falls on a piece of land and then moves down the watershed as runoff into an estuary or an ecological factor that can be combined into a set of parameters conducive to a particular species.

Five resource management issues at the Reserve are particularly conducive to assessment using GIS models and simulations. Determining the restoration and recharge potential of acquisitions prior to clearing or planting improves long-term success of work completed and insures better allocation of funds. Simulation of rain events, historic and with varying levels of development, illustrate potential areas of freshwater flows too high or too low for existing ecosystems. Determining areas of sensitivity to specific human uses allows the mapping of buffer zones to increase protection of endangered species and rare communities. Testing hypothesis about rates of and areas advantageous to invasive non-native species will lead to improved ability to prioritize removal efforts and requests for realistic manpower and funding.

RESEARCH

CURRENT

The Reserve's Research program provides the scientific information necessary to support an adaptive management strategy for conservation of natural biodiversity for the area managed by the Reserve. This strategy entails 1) identifying areas of scien-

tific uncertainty, 2) planning and conducting field experiments to test hypotheses related to real-world management strategies, 3) exporting this information to environmental managers and decision makers, and 4) recommending improved management strategies based on the results of these experiments. A primary function of the Research program is to develop and monitor indicators of natural biodiversity at the levels of watershed, community, population and organism. This science-based hierarchical approach is necessary to more effectively manage the Reserve's natural resources and assess, prioritize and improve the effectiveness of future habitat restoration projects. To be successful, these activities are closely coordinated with the Reserve's Resource Management, Public Access and Education programs.

Several long-term monitoring projects make up the foundation of the research department at RBNERR. Although special high-interest research projects are often funded and staffed by temporary Reserve staff, these monitoring projects are priorities for meeting the core objectives of understanding natural versus human induced environmental changes. The projects presented here represent key efforts towards meeting research goals as established in the 2000-2005 management plan.

Water quality

The record of long-term physicochemical measurements for the surface waters managed by the Reserve began in 1970 (Yokel, 1975). Differences in sample locations, analytical methods and reporting techniques allows only for gross generalizations to be made regarding trends in these datasets. Christensen (1998) analyzed monthly rainfall, secchi depth, surface and bottom dissolved oxygen, turbidity, temperature and salinity data collected by the Reserve's staff at seventeen fixed stations throughout the Rookery Bay Aquatic Preserve from 1986 to 1992.

Presently, the Reserve's staff maintains four continuous monitoring stations, contributing to the National Estuarine Research Reserve system-wide monitoring program (SWMP) and jointly funded by NOAA and the State of Florida. These stations record temperature, salinity, dissolved oxygen, pH, depth and turbidity at one-half hour intervals. Two stations, lower Blackwater River and lower Henderson Creek, have been collecting data since April 1996. Two additional stations, Faka Union Bay and Fakahatchee Bay were established in 1999 to expand the area studied by this monitoring program. All four stations were located in the mesohaline portion of each estuarine system in water having similar depths and dry season salinity. The primary purpose of the Reserve's current monitoring program is to supplement the biological data being collected for assessing hydrologic watershed restoration projects. This recent monitoring strategy lacks the spatial coverage of previous efforts but collects data on time scales previously unavailable and is providing insight into biologically significant short-term changes in physicochemical conditions.

Southern Golden Gates Restoration Baseline Monitoring

Pumpkin Bay, Faka Union Bay and Fakahatchee Bay lie downstream of the Southern Golden Gate Estates, a failed development that built 813 miles of roads and 138 miles of canals during the 1960's to drain the swamps of Collier County in SW Florida. Over-drainage through the Faka Union Canal has resulted in a permanent 8-12 ppt salinity decrease in Faka Union Bay compared to adjacent Pumpkin and Fakahatchee Bays. Canals and roads in the Southern Golden Gate Estates, will be removed in 2001 providing a more even distribution of water to the three bays. The planned hydrologic restoration will reduce the flow out of the Faka-Union Canal by 99% and provide a more even distribution (sheet flow) of water to the coastal wetlands and bays of the 10,000 Islands.

In July 1998, we began a stratified, random, fisheries-independent trawling program to establish current baseline distributions and relative abundances of fish and invertebrates prior to the restoration. All three bays have significantly different daily and annual salinity regimes. Pumpkin Bay has the lowest level of salinity fluctuation

and Faka-Union has the highest level. The largest monthly catches for all bays occur during the end of the wet season (Aug - Nov). but Pumpkin Bay monthly catches are 2-4 times greater than the other two bays during the wet season. Faka-Union Bay has become a point source for freshwater in a saltwater system, while the watershed draining into Pumpkin Bay has had overland flow channeled into canals. Fakahatchee Bay has the least affected watershed of the three studied.

Species specific differences in abundance are demonstrated by three goby species. These differences might make these gobies good indicator species. Gobiosoma robustum (code goby) prefers higher salinities, seagrass beds and algal mats. Pumpkin Bay and Fakahatchee Bay exhibit higher salinities with more algal bycatch and a potentially higher number of code goby. Microgobius gulosus (clown goby) and Microgobius thalassinus (green goby) prefer muddy bottom types. Faka Union Bay exhibits lower salinities with less algal bycatch and appears to have less consolidated bottom, with potentially higher number of clown and green gobies.

This study will continue as a long-term monitoring project. Although this study was primarily intended to provide baseline data for the Southern Golden Gates Estates restoration, other bays will be added as time and staffing permits. Rookery Bay was added as a trawl site last year.

Macroinvertebrate inventory

Estuarine species respond to seasonal changes in freshwater input which signal important life cycle stages such as reproduction and migration patterns. Although these species are naturally adapted to salinity fluctuations, some species are better adapted (euryhaline) than others (stenohaline) to tolerate these fluctuations. The two species chosen for these studies exhibit different salinity tolerances. *Eurypanopeus depressus* is a euryhaline crab and *Petrolisthes armatus* is stenohaline crab. These crabs are common inhabitants of oyster reefs. Once they recruit to a reef, they must remain and tolerate habitat conditions in order to survive. These species are also known to be important items in the diet of fish and birds.

Estuarine species have evolved to respond to natural seasonal patterns of salinity change to guide important life history events such as reproduction and larval dispersal. Corresponding to the altered salinity patterns, we observed significant differences in reproduction, recruitment and population stability of estuarine crab species between Blackwater River and Henderson Creek.

In order to restore the freshwater inflow pattern to a more natural condition, the Reserve has received a grant through the National Marine Fisheries Service to finance a retrofit of the Henderson Creek weir to allow for a more gradual release of freshwater into the estuary. Based on these studies, the goal of this future restoration will be to release more water at the Henderson Creek weir early in the rainy season in order to reduce the need to release large amounts late in the rainy season in response to flooding in the watershed. Further research is needed to fine-tune this water release strategy to improve estuarine habitat while maintaining adequate flood control and the prevention of saltwater intrusion.

Turtles

Australian pines, *Casuarina equisetifolia*, were planted in southern Florida during the early 1900's, for protection against wind and storms (Craighead, 1971; Nelson, 1994). The shallow root system of this invasive exotic tree species makes them more susceptible to the effects of storm winds and erosion than native plants (Armentano et al., 1995). When they fall they may obstruct access to beaches by gravid female sea turtles (Schmelz and Mezich, 1988; LeBuff, 1990; Reardon, 1998). In March of 1998, Rookery Bay National Estuarine Research Reserve (RBNERR), Florida Department of Environmental Protection (FDEP), began a large scale restoration project to remove 250 acres of live Australian pines and snags from Keewaydin Island.

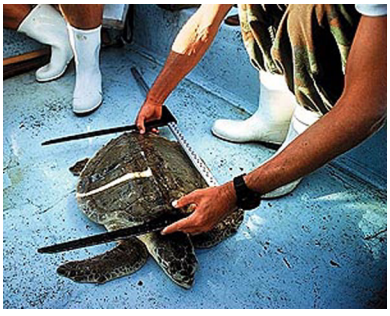
Keewaydin Island, also known as Key Island, is a 12 kilometer, 1300 acre, primary barrier island off the coast of Naples, Collier County, Florida. Historically this island has been a significant nesting ground for loggerhead sea turtles, *Caretta caretta* (Addison et al., 1998). During the 1998 nesting season, Rookery Bay and the Conservancy of Southwest Florida began plotting the location of nests and false crawls via Global Positioning System (GPS), in order to document the effect of Australian pine removal on sea turtle nesting (Ryder et al., 2000).

A comparison of loggerhead nesting activity before pine removal and after removal indicates an increase of activity in areas previously inaccessible. Although there is variability in total number of nests and false crawls before and after Australian pine removal, activity has increased in areas where fallen pines were removed. Rookery Bay NERR and the Conservancy will continue monitoring Keewaydin Island over the following years. These data will be compared to the historical data (1990 - 1997) previously collected by the Conservancy. The results of this study will determine whether the removal of Australian pines alters nesting patterns. If these patterns shift as a result, the value of Australian pine removal as a management strategy on nesting beaches will be established.

In order to prevent further decline of threatened and endangered species of sea turtles, it is essential to understand how environmental conditions, such as beach altering activities, affects nesting and hatchling success. This information can then be taken to land managers to ensure "best management practices" on coastal beaches and prevent further degradation of suitable nesting habitat. Natural processes such as erosion are unavoidable and can not be permanently stabilized however, the encroachment of human impact and spread of invasive plant species on beaches are factors that can be managed. Research has been conducted to identify impacts on sea turtle nesting beaches and means to alleviate these impacts are receiving further investigation. One growing impact is the invasion of Australian pines on sea turtle nesting habitat in southern Florida. The pines have been shown to decrease sand temperature, which may affect the sex of hatchlings, and snags have greatly reduced the availability of suitable nesting beach. By comparing the historic loggerhead turtle nesting data on Keewaydin Island to the data collected after the pine removal, we will obtain a better understanding of how Australian pines impact nesting beaches. Furthermore, the results of this study will also determine whether their removal alters nesting patterns. If these patterns shift as a result, the value of Australian pine removal as a management strategy on nesting beaches will be established.

Bird monitoring

The National Audubon Society and its Collier County chapter have been active in preservation activities related to Rookery Bay and throughout the county for decades. Dr. Theodore H. Below, National Audubon Society warden biologist, has been monitoring bird populations and activities in Rookery Bay and surrounding coastal areas since 1972. With the help of RBNERR staff and local volunteers, tagging and counts of several species have been conducted throughout the Reserve. Species of special interest are the Florida scrub-jay, translocated here in 1989 from the Archibold Biological Station in central Florida, and least terns, an endangered species due to loss of unpopulated sandy beach. Other birds monitored in the area include osprey, brown pelicans and gulls.



In 1989, a study by Mumme and Below was initiated at RBNERR to evaluate translocation as a technique for restoring the Florida scrub-jay to unoccupied portions of its historic range. The goals of this study were to determine the long-term viability (pros and cons) of the translocation of Florida scrub-jays as a resource management technique; to develop translocation field techniques; and to generate detailed data on the population dynamics of a small, isolated, reestablished colony.

In 1989, 1990, and 1995, a total of twenty Florida scrub-jays were brought from

Archibold Biological Station in central Florida and released into suitable scrub habitat at RBNERR. The effects of translocation, population dynamics, duration of residency and nesting success of these birds and their descendents were followed until 1997 when the study ended. Mumme and Below (1999) concluded translocation, under certain circumstances, is a viable technique for restoring the threatened Florida scrub-jay to unoccupied portions of its historic range but is not an acceptable substitute for the management of existing populations (Mumme and Below, 1999). The remaining Florida scrub-jay population at RBNERR is still being monitored at RBNERR by Below for nesting success and survivorship.

The least tern (*Stern antillarum*) is listed as a threatened species by the Florida Game and Fresh Water Fish Commission (FGFFC, 1997) and protected by the Florida Endangered Species Act and the Federal Migratory Bird Treaty Act. A least tern productivity study was begun in 1982 and local tern colonies have been monitored regularly during the summer breeding season (Below, 2000). In April 2001, Rookery Bay National Estuarine Research Reserve (RBNERR), in cooperation with the Florida Fish and Wildlife Conservation Commission and the local Audubon Society, initiated the closure of an important least tern nesting sandbar located within RBNERR managed lands. This emergent sandbar, near Cape Romano, is posted as a "No Landing" area in order to protect least terns from human disturbance during their critical breeding season. Adult terns, tern nests and chicks are monitored weekly to determine seasonal nesting success and assess population trends and all species are noted (Below, 2000).

Harmful Algal Blooms (HAB)

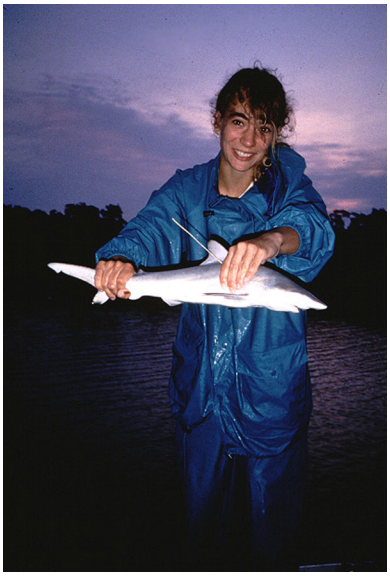
Harmful algal blooms (HABs) occur throughout the world, and have been increasing in occurrence, risk to human marine animal health, and impact on estuarine related economies in every coastal area of the United States (Culotta 1992, Baker 1998). Assessments by the National Fish and Wildlife Foundation partnered with NOAA (Boesch et al. 1997) concluded that areas of research requiring immediate attention related to these algal blooms are development of early warning systems and research supporting understanding and prevention of HABs. There is no clear cause and effect model for bloom occurrence. The most notable HAB in southwest Florida is "red tide", large population pulses of *Gymnodinium breve*. *G. breve* blooms occur annually in the Gulf of Mexico.

Monitoring of *G. breve* is coordinated in the State of Florida by the Florida Marine Research Institute (FMRI), and volunteers collect samples at several points within RBNERR waters. Results of this project can be viewed at http:// www.floridamarine.org.

VISITING INVESTIGATORS

A key RBNERR goal is to facilitate and support research in the Reserve conducted by visiting investigators, through partnerships with universities, research institutions and agencies. The Reserve continues to expand facilities and equipment to support visiting investigators at Rookery Bay. In addition to establishing two research field stations with overnight accommodations and boat access at Cannon Island and Goodland, RBNERR offers two graduate fellowships per year, with NOAA support. A recently established partnership with Florida Gulf Coast University (FGCU) has resulted in an increase in student and faculty research and courses conducted at the Reserve. The proposed RBNERR Environmental Learning Center facility, including two research laboratories and a wet lab, will significantly increase visiting research opportunities at the Reserve by universities and research institutions.

Research completed by visiting investigators covers a diversity of topics including archeology, birds, natural disturbances, dunes, fisheries, invasives, invertebrates, mangroves, paleoecology, phytoplankton, public access, restoration, turtles, tortoises, and water quality. A database with research synopsis and contact information is



maintained at RBNERR. A collection of research papers, including published reprints, technical reports and unpublished manuscripts will soon be housed at the FGCU library, increasing accessability.

RESEARCH NEEDS

Science-driven management is a high priority at RBNERR, and visiting investigators and graduate students provide much of this research. Information on immediate research needs can be used both as ideas for project direction and as support for funding proposals by university researchers and their students. These projects outlined below are of special interest for RBNERR because they address objectives from the management plan.

Water Quality

Water quality monitoring is a key component of RBNERR's in-house research program. The Reserve's long-term data sets reveal many interesting ecological patterns deserving of further research.

- Determine the relative importance of nutrient input from mangrove forests relative to freshwater runoff and tidal export /import and sediment resuspension
- Sampling of storm and tidal events to construct a more accurate nutrient budget
- Detailed studies of the association of light attenuation and nutrient dynamics to determine the feasibility of setting nutrient runoff reduction goals
- Scientific evaluation of best management practices for stormwater treatment by golf courses, residential areas and agriculture to develop landuse recommendations to ensure avoidance of noxious algal blooms or increased hypoxia
- Determine the influence of watershed landuse patterns on the biogeochemical conditions of estuarine systems to guide stormwater management
- Monitor estuarine habitats and organisms in response to watershed water management activities to determine the biological significance of altered quantities and patterns of freshwater inflow

Watersheds

Little research beyond species inventories has been completed on the upland and freshwater communities within the Reserve and the Aquatic Preserves. Research on communities similar to those in southwest Collier County does exist, however, the work has been completed in different geographic locations with very different substrates and climate. Consequently, the areas of research needed for the terrestrial portions of RBNERR are wide open.

- Verify encroachment from mangroves due to saltwater intrusion
- Studies evaluating water tables, chloride concentrations, nutrient cycling, transpiration, fire intervals, invasive plant susceptibility, and groundwater movement would address key RBNERR management issues and assist in restoration efforts, as well as modeling of future development impacts on RBNERR's estuaries.
- Surveys are needed to determine the full extent of residual toxins in areas of future development or restoration to avoid chronic and acute distress of estuary invertebrates, fish and wildlife.
- Accurate assessment of groundwater levels will lead to better management of seasonal stormwater and residential retention areas

Wildlife

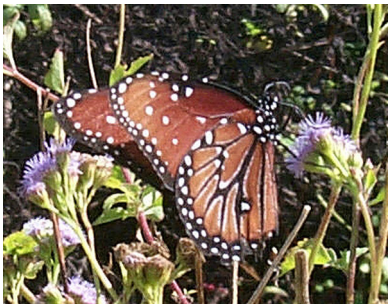
Research on bird populations has been conducted since the '60s by Dr. Ted Below, warden for the Audubon Society in southwest Florida, aided by local volunteers and RBNERR staff. Because of these efforts, a large number of specific questions about bird behavior and responses have been identified.

- Identifying and evaluating limiting factors affecting the size of least tern nesting colonies
- Assessing the behavioral and demographic responses of least terns to an increase in human disturbance

- Applied research projects exploring methods to maintain, enhance or expand existing least tern nesting habitat to promote increased breeding productivity
- Banding projects addressing shorebird population overwintering patterns and wintering site fidelity
- The relationship of local invertebrate food resources, shorebird feeding regimes, and feeding disruption from human disturbance on shorebird surivorship prior to and during migration
- A study of the effects of coastal mosquito control spraying (timing, deposition levels, and pesticides) on shorebirds
- Habitat relationships between nesting/roosting sites and feeding sites, incorporating watershed management issues
- Degree of interspecific and intraspecific site fidelity to nesting/roosting islands and feeding sites and their adaptability to rapidly modified habitats
- Breeding success by species, intraspecific and interspecific resource competition, energy needs, the relationship between breeding/fledgling success and food resource availability, and nesting seasonality
- Effects of increased human disturbance at nesting/roosting sites on reproduction and survivorship
- Evaluation of the potential threat of environmental contaminants found in coastal waterbird feeding areas associated with intensive agricultural activity, using the trace element contaminant concentration levels found in waterbird tissue, excrement or feathers
- Possible correlations between coastal waterbird (terns and pelicans) feeding success and turbidity levels caused by beach renourishment by dredging
- Determine the level of activity/disturbance from increased boat traffic that ospreys are able to tolerate at nest site locations and the effects of this disturbance on nesting success and productivity
- Compare local osprey nesting productivity and survivorship with populations in everglades national park before, during and after the everglades restoration project
- Use ospreys as biological indicators by studying the impact of agricultural pesticide runoff on osprey reproduction and survival
- Marking or tagging projects which would improve knowledge of osprey pair bond formation and duration, survivorship and additional life history data
- Comparing annual food availability to osprey chick survival and fledgling success
- The relationship between scrub-jays and scrub habitat that is affected by humans (fire-suppressed, fragmented, fire-restored)
- Comparing the established RBNERR, translocated, scrub-jay population with populations from both other translocation sites and historical sites to further evaluate this management technique
- The energetic and physiological ecology of the florida scrub-jay are little studied but could yield much insight into the age-and stage-specific costs of reproduction, molt, territory defense, helping behavior, and dispersal
- Mounting evidence suggests that florida scrub-jays succumb to episodic arboviral diseases, but the overall importance of disease in their population biology is in need of further research

Other wildlife are not as well studied in the Reserve, with the exception of crocodiles. These specific animal studies are important to success of multi-species management at RBNERR.

- More intensive and systematic trapping is needed to determine population composition, size and distributions
- Comprehensive biological/ecological studies of individual species or guilds of species is essential to understanding the role of fire and hydroperiod changes on RBNERR's wildlife
- A quantitative evaluation of population size, areas of refugia, and seasonal migra-



tion paths to assist in delineating manatee zones and avoidance of boating accidents.

Estuarine Ecology

Despite the fact that RBNERR's estuaries are the most studied community at the Reserve, many areas of management concern require further research. Mangrove populations are declining rapidly worldwide, bringing greater urgency to understanding the preservation of our mangroves and connected ecosystems upon which they depend.

- Research is needed to document 1) reduction in the area of favorable salinity; 2) loss of important benthic habitats; 3) reduction in the recruitment of fish eggs and larvae; and 4) damage to benthic fauna, and to determine mechanisms of, and the thresholds beyond which, this damage occurs
- Resurvey of the regions' seagrass habitats to determine the extent of the loss of this habitat
- Long-term monitoring of four coastal and four backwater seagrass habitat monitoring transects, along with ancillary data relating to factors affecting light attenuation, salinity fluctuation and eutrophication
- Research on understudied benthic habitats and processes, especially the role of macroalgae, sponge beds, oyster reefs, vermetid reefs, and salt flats as habitats

- The role of benthic bacteria in carbon cycling of mangrove and macroalgae detritus
- Development of paleobiological techniques to map historic seagrass and benthos along with an understanding of the factors limiting the distribution of seagrass and benthic fauna
- Understanding of the role of macroalgae as a habitat and food source for fish and macroinvertebrates
- Develop methods that detect changes in forest health prior to mortality
- Monitoring of sediment accretion rates in relation to sea level increases and land subsidence monitoring tools also need to be developed to provide early warning of forest degradation due to herbicide runoff from nearby golf courses, residential areas, and agriculture
- Develop monitoring methods to examine the subtle changes in mangrove forests function and structure associated with anthropogenic effects
- Studies are needed to link the function of overwash, fringe and basin mangrove forests to nutrient dynamics and water quality of rookery bay, including estimates of atmospheric inputs of nutrients and their influence on mangrove forest productivity
- Quantify the rate of organic carbon exchange associated with below ground productivity (root turnover rate), along with anaerobic respiration of the forest floor
- Quantify the link between mangrove forests and the secondary productivity of adjacent estuaries the role of mangroves as habitats for recreational or commercially valuable species and as a basis of the detritus-based food web leading to these species needs to be empirically established verification that mangrove forests are providing food to mobile estuarine consumers
- Ecological role of dissolved organic matter exported from mangrove forests
- Quantitative measurement of the energy flow associated with the basin forest detritus-salt marsh mosquito food

- Significance of the export of decomposing woody debris, particulate organic matter and dissolved organic matter during and following a destructive storm to the organic export from mangrove ecosystems
- Need for a comparative analysis of predation efficiency and prey selection in relation to the degree of tidal inundation for mangroves, non-vegetative mud and seagrass habitats
- Document the value of mangroves as shoreline stabilizers to provide incentive to private and public landowners to restore and protect fringing mangrove forests

from removal or trimming
- Quantify cumulative impacts of nutrients and contaminants in stormwater runoff, the drift and deposition of mosquito control pesticides, and alterations in freshwater and tidal exchange
- Understand the effects of changing pH, salinity and hydroperiod on the mobilization of heavy metals, polyaromatic hydrocarbons (PAHs), pesticides and nutrients
- Document exchange and bioaccumulation of contaminants in fauna associated with mangrove forests or dependent upon the mangrove detritus-based food web

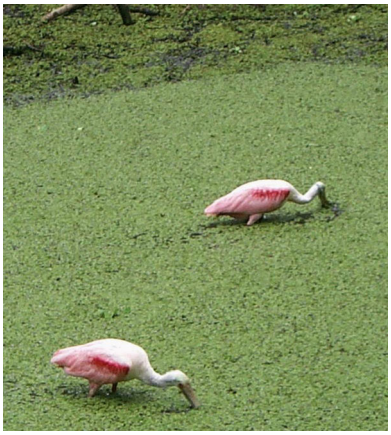
Restoration Science

Restoration of new land acquisitions is an important RBNERR goal and covers a wide range of community types and hydrologic alterations. Due to limited staff and the process for obtaining and spending restoration funds, comprehensive monitoring and baseline studies that provide important direction for future work are not always feasible. Because restoration often creates a short-lived transitional shock response followed by differing permanent communities, establishment of long-term monitoring projects is encouraged.

- standardize habitat restoration methods and monitoring protocol
- factors influencing the spread of invasive exotic species, particularly Australian Pine (Casuarina equisetifolia) and Brazilian Pepper (Schinus terebinthifolius) into mangrove forests

Summary

Rookery Bay NERR is an active research reserve, with outstanding facilities and the opportunity to study a large diversity of ecosystems endemic to southwest Florida, but of great national and international interest. Implementing and monitoring different restoration techniques provides additional potential for long-term environmental studies to support improved restoration success. RBNERR has an active education and outreach program as well, partnering with Florida Gulf Coast University and other science consortiums. The new learning center will open the reserve to an even broader audience, providing increased access and interpretive displays for all ages.



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